Sky and TELESCOPE

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First Reports of Mercury's Transit

Lunar Cartography

Some Problems of Stellar Rotation — I

The Fine Structure of Solar Prominences — II

American Astronomers Report

Lick 120-inch Photographs — VI

Northern and Southern Star Charts

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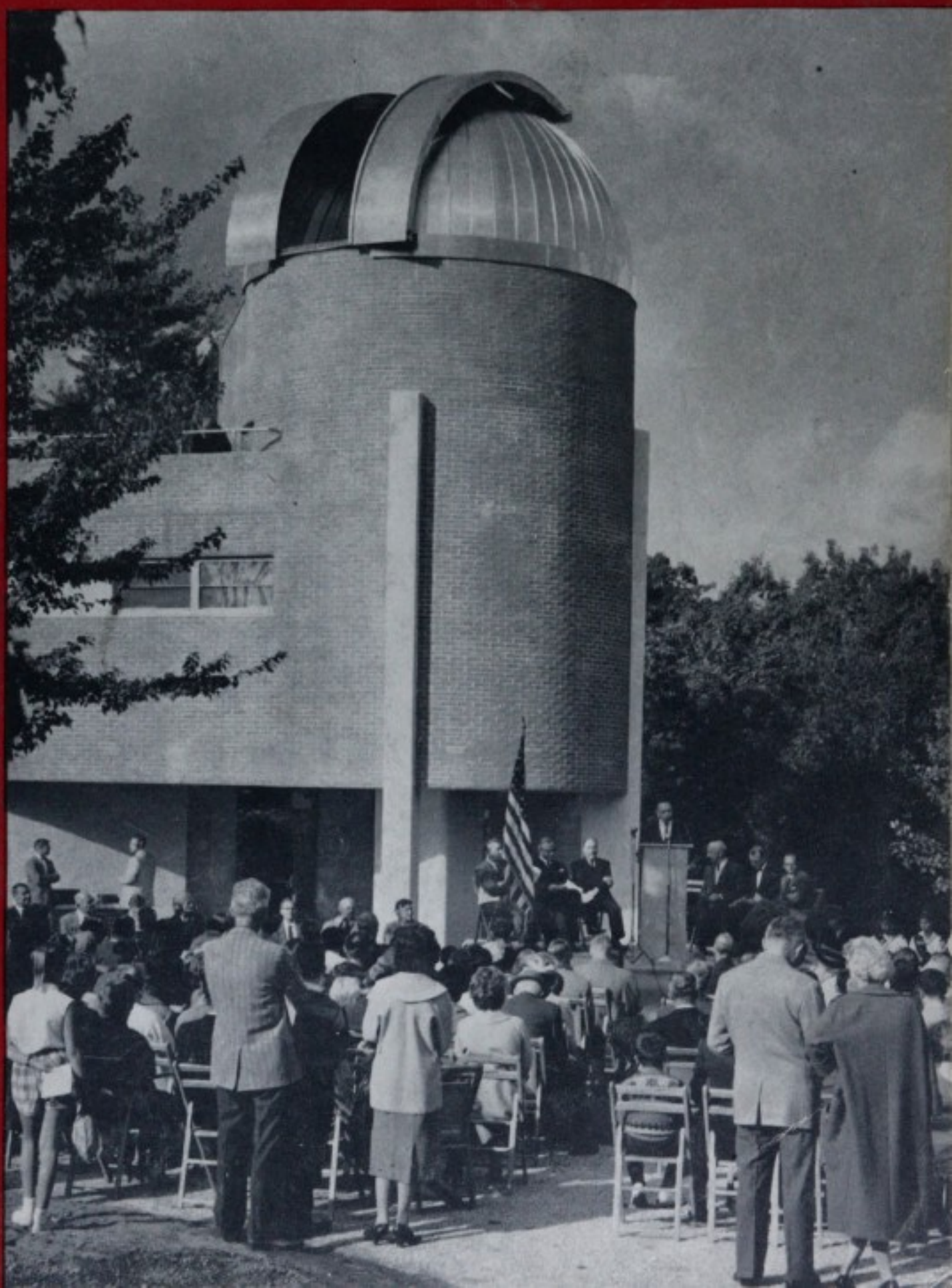

Stanford dedication

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COMMENTS BY VICTOR GOEDICKE

Director,
Ohio University Observatory

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Sky and TELESCOPE

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Vol. XX, No. 6 DECEMBER, 1960

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COVER: Dedication ceremonies at the Stamford Observatory, October 2, 1960, culminated a community project at Stamford, Connecticut, that was described in this magazine in September, 1959 (page 622). Third from right on the speaker's platform (next to the lectern) is Dr. J. J. Nassau, of Cleveland's Warner and Swasey Observatory, who gave the dedicatory address, "Exploring the Universe." The 18-foot converted silo-top dome will house a 22-inch Maksutov catadioptric telescope, now being made. The 100-seat lecture room is complete, and space is available for a library, darkroom, and other facilities. Gordon E. Johnson is the observatory architect, and Frank Mercedes and Sons the builders. In regular operation elsewhere on the grounds of the Stamford Museum and Nature Center is the Edgerton Planetarium. Photograph by Carol Werner.

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First Reports of Mercury's Transit

OBSERVERS throughout the United States generally were able to see Mercury pass across the sun's disk on November 7th, although many were harassed by clouds. Even before the 4½-hour event was over, the first report by telephone was received at the SKY AND TELESCOPE office. As this issue was then going to press, only a brief mention of early accounts can be given here. A more detailed summary of observing results will be published later.

Northeastern watchers were, as a rule, able to catch only portions of the transit through breaks in the stratocumulus cloud deck that blanketed much of the region until Mercury's egress. These observers included H. Stubbs, Milton, Massachusetts; L. Fraser, Bridgewater, Connecticut; P. Del Vecchio, Paterson, and R. Wurgel, Union City, New Jersey; C. Kapral, Luzerne, and R. Platt, II, Feasterville, Pennsylvania. At Buffalo, New York, Ernst Both timed second and third contacts through breaks in clouds that occasionally brought heavy snow flurries.

Farther west and south, it was generally clear. From the Middle West, successful observations were reported by correspondents J. Kuecken, Evendale, Ohio; R. Johnson, Chicago, Illinois; H. Cornell, Milwaukee, and R. Buckstaff, Oshkosh, Wisconsin; R. Cox, O'Fallon and H. Lang, St. Louis, Missouri. At some of these localities, atmospheric turbulence caused the sun's image to boil severely and made contact timing difficult.

Eleanor Matter, of the Virginia Junior Astronomers, used her school lunch period to view and draw the transit at Arlington. The weather was fine at Knoxville, Tennessee, for timings by J. Brown; at Decatur, Georgia, for L. Abbey, Jr., who made 14 micrometer measurements of the planet's diameter; and at Jupiter, Florida, where R. Citron used an 8-inch reflector.

Group observations were organized by many amateurs. At Silver Spring, Maryland, G. R. Wright invited 10 elementary school science supervisors to view the early stages of the transit. In Miami, Florida, writes Carolyn Tripp, the Southern Cross Astronomical Society set up two stations from which to time the event. The 20-inch Clark refractor of Chamberlin Observatory at Denver, Colorado, was used for photography by K. Steinmetz and several other members of the Denver Astronomical Society.

A novel observation, suggested by the French astronomer A. Dollfus, was tried at Las Cruces, New Mexico, by B. Smith and others. They measured Mercury's size photoelectrically, a small diaphragm

(Continued on page 384)

D. W. G. Arthur has circled on this photograph, of the Mare Humorum region, those features whose co-ordinates have been precisely measured by photography in the 20th century. Five crosses represent the only prephotographic standard positions in this area. Pictures with this article were supplied by the author.

Lunar Cartography

D. W. G. ARTHUR, *University of Arizona*

IT IS VERY PROBABLE that astronomers of the future will divide the history of mapping the lunar surface into three parts – a first period commencing soon after the invention of the telescope and culminating in 1878 when J. F. J. Schmidt's famous chart was published; a second period when the moon was mapped using photographs taken from terrestrial observatories; and a third and final stage when the moon's surface was surveyed in detail using photographs taken from space vehicles orbiting close to the lunar surface.

The first era produced some deservedly famous maps. With small telescopes and inadequate appliances, W. G. Lohrmann, J. H. Mädler, and Schmidt compiled lunar atlases of a quality that has scarcely been surpassed. Yet, although we must admire these early efforts, they have numerous defects that make them unsuitable for many modern scientific purposes.

These early maps are mere mosaics of telescopic drawings, held in position by a network of standard points which were not only too few but very inaccurate. Consequently, the 19th-century atlases contain almost innumerable errors of dimension and position. Moreover, as all observers know, there are parts of the lunar surface, such as the areas north of the lunar Alps and west of the Caucasus, whose delineation defies even the most skilled visual worker. Indeed, these regions can be surveyed only with the help of photographs.

The first effective lunar photography, starting soon after the publication of Schmidt's chart, ushered in the second period of mapping. It then became possible to survey all the moon's surface features with uniform accuracy, much higher than that of the prephotographic maps, and little inferior to that of the standard points. In addition, the standard points themselves could be fixed with considerably greater precision and much less labor.

The first requirement was a new triangulation of the moon's surface by measurements on photographs, in order to provide a denser and more precise network of reference points. This need was met shortly before World War I by the German professional astronomer J. H. Franz and the English amateur S. A. Saunder. Their final catalogues together contain co-ordinates of close to 3,500 well-determined points, a good base for a

Julius Franz's photographic measurements have proven invaluable to modern lunar cartography. Director of Breslau Observatory, he died in 1913.

modern map. The accompanying photograph of the Mare Humorum region demonstrates the comparative densities of the prephotographic and photographic triangulations.

Franz stated the positions of the lunar features he measured in terms of selenographic longitude (λ) and latitude (β). These co-ordinates are analogous to their geographical counterparts. On the moon, the zero meridian of longitude is that passing through the center of its disk seen under conditions of mean libration. Poles and equator are defined by the moon's rotation, as in the case of the earth.

Saunder, however, expressed selenographic positions by means of the much more convenient direction-cosines (ξ, η, ζ), which are the same as the three-dimensional rectangular co-ordinates of the point if it lies at unit distance from the moon's center. In fact, ξ and η are the standard orthographic map co-ordinates, and practically all modern lunar maps employ them.* These direction-cosines have remained unnamed, but selenographers may find it helpful to imitate usage of military cartographers and call them *westing*, *northing*, and *earthing*, respectively.

*The direction-cosines of a point whose selenographic longitude and latitude are λ and β, respectively, can be computed from the relations: $\xi = \cos\beta \sin\lambda$; $\eta = \sin\beta$; $\zeta = \cos\beta \cos\lambda$.

TRIANGULATIONS OF THE MOON'S SURFACE

Catalogues	*No. of Points*	*Standard Error**	*Co-ordinates Given*
Prephotographic (to 1875)	157	20′	λ, β
Franz (1901)	150	1.2	λ, β
Saunder (1905)	1,433	0.2-0.7	ξ, η
Saunder (1911)	2,885	0.2-0.7	ξ, η, ζ
Franz (1913)	1,366	1.2-4	λ, β

*Average values for longitudes and latitudes of points near the center of the lunar disk.

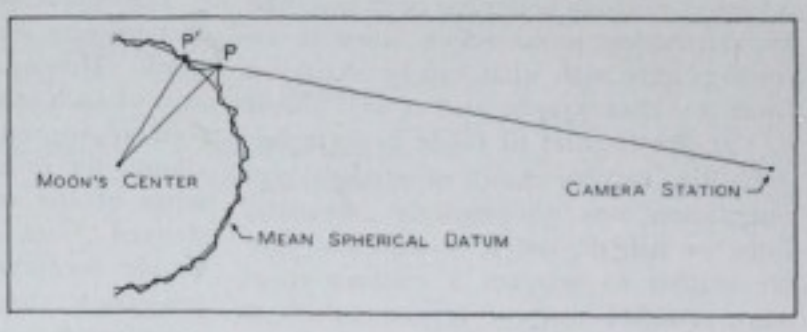
Both Franz and Saunder computed their positions from the photographic measures as if the points were all on a single spherical surface, although they were aware that this assumption is an approximation. They actually determined not the point itself, but its projection on the spherical surface, that is, the intersection of the line of sight with that surface. Hence, both the Franz and Saunder positions are subject to errors that are roughly radial to the mean center of the disk, but these errors are important only for very high or very low points near the limb.

Cartographically, there is not much that can be done about these errors. It is true that if a point is repeatedly determined from pictures taken at very different librations, its apparent position will be found to vary systematically with the libration. The variations can then be analyzed to find the absolute altitude and the corrected position of the observed point, and such calculations were made by both Franz and Saunder for some features. But the smallness of the libration and the limited resolving power of lunar photographs set severe limits to the accuracy and usefulness of this kind of analysis, and the results are not too trustworthy. The latest research in this direction is by G. Schrutka-Rechtenstamm of Vienna University Observatory, who has reworked the observations in the first Franz catalogue, obtaining corrected positions and absolute altitudes of 150 points.

It is quite impracticable for the cartographer to apply such complicated and laborious computations to the innumerable detail points of a map. As it happens, these errors are compressed by foreshortening in the usual orthographic map, and their effects are almost negligible. But they still cause serious difficulties when we seek to determine the height of a mountain near the limb from the length of its shadow.

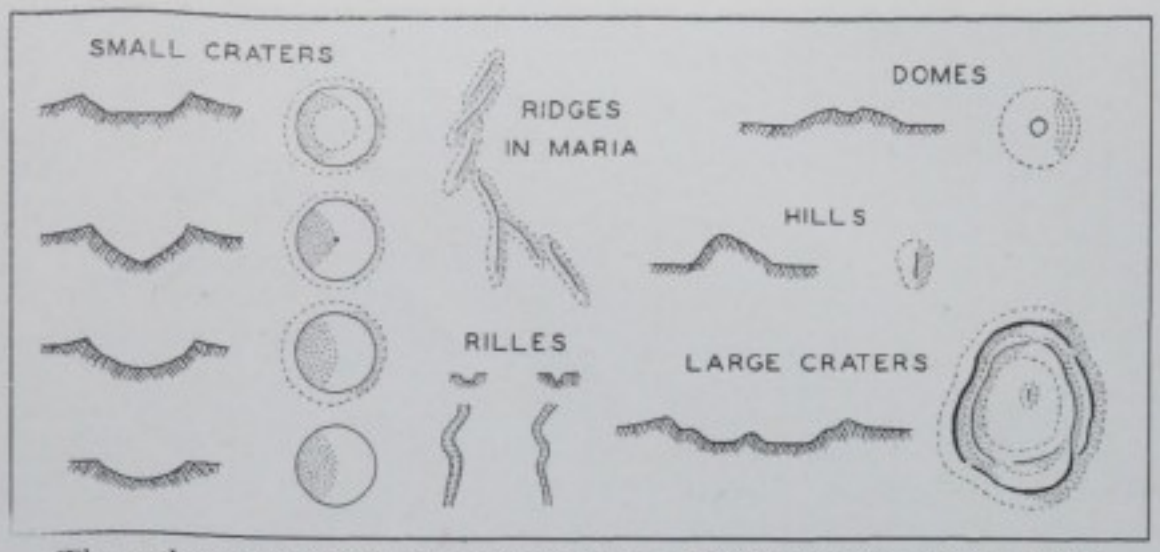
Franz and Saunder gave the second period of lunar mapping a magnificent start, but what followed was an anticlimax. Lohrmann, Mädler, and Schmidt had been competent cartographers, since they had the mathematical knowledge, manual dexterity, and the good taste that are essential in constructing maps. They were followed in this century by others who did not share these abilities. In particular, the charts of W. Goodacre and H. P. Wilkins are poor specimens of lunar cartography. To be useful, a map must be clear, unambiguous, and definite, and if possible it should have a certain aesthetic appeal. In these respects, the maps of Lohrmann, Mädler, and Schmidt were successful. Nowadays, for lunar charts prepared from modern data, we may justly ask that they also be highly precise in positions, dimensions, and content. The English maps fail to meet either set of criteria.

Important though photographs are, they have their limitations. Even the best do not show objects less than 600 yards across, and therefore are equivalent to naked-eye views from 2,000 miles above the lunar surface. Maps based on such material can never have the detailedness of terrestrial



Measurement of a lunar feature on a single photograph gives not the true position P but its projection P′, on an adopted spherical surface of reference.

The quality of J. H. Mädler's lunar mapping is shown by his 1841 chart of the moon's north polar region, with a 3¾-inch refractor. Points marked with capital and Greek letters were measured with a filar micrometer.



The author recommends these conventions in charting details from a photograph. The cross sections of the features are schematic.

topographic charts. All that can be taken from a lunar photograph with reasonable speed and precision are the dominant lines of the relief, namely, the crests and bases of slopes, although we can also estimate roughly the steepness of a slope.

This has a bearing on the choice of a suitable scheme of conventions for a contemporary map of the moon. Prephotographic selenographers represented the relief by *hachures,* which are short strokes in the direction of maximum slope. To my mind, nothing better has been invented for portraying lunar relief, since it accords exactly with what can be extracted from the photographs and is well suited to the peculiarities of lunar topography.

Philipp Fauth's choice of contour representation was not entirely fortunate, since we still do not have sufficient data on heights to warrant a contour map. Also, unaided contour representation is ambiguous, as can be seen from the sample Fauth map in Sky and Telescope (November, 1959, page 20). It is also evident that this style does not deal successfully with the smaller details.

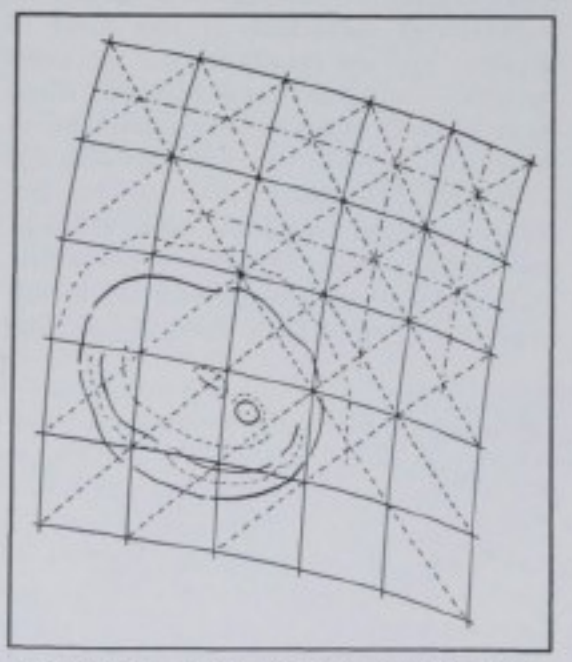
Unfortunately, draftsmen skilled in hachure work are fairly scarce. A simpler scheme of conventions, demanding much less skill and time, should be considered. In this, crests of slopes are shown as solid lines, and bases of slopes as broken lines. To give a map plasticity, the eastern slopes can be shaded. With these and a few other conventions for minor features, a clear and definite picture of lunar relief should be possible.

All major lunar maps have used the standard orthographic projection, in which each point is projected onto the plane of the moon's mean limb by dropping a perpendicular to this plane. This is still the best projection for normal astronomical purposes, since it shows the shapes of lunar features much as they appear on photographs or in telescopic views. However, there is now some demand for lunar maps more akin to terrestrial topographic charts, showing each surface element as if viewed from directly above.

In planning such a map, both the character of the material available and the needs of the cartographer must be considered. As already indicated in our discussion of the Franz-Saunder network, in terms of map distances the positions become more and more inaccurate as we go toward the limb; also, very high or very low points are subject to gross errors which are radial to the moon's center of face. Lofty crater walls and ridges permanently hide certain areas near the limb, and these must therefore be shown as blank spaces on the map.

The convenience of the cartographer dictates very simple types of map projections. The orthographic, in which the area of each map sheet is projected on its own appropriate map plane, has strong claims, for in this case the map co-ordinates of the standard points are easily derived from the direction-cosines by simple formulae. For any other chart projection, the computation of the map co-ordinates is much more laborious.

One other projection has already been used for some lunar charts. This is the stereographic, which retains the shapes of small details and has the unique property of rigorously preserving the shapes of circles of all sizes. In view of the circularity of most lunar craters, this feature of the stereographic projection promises to be extremely useful, and would simplify much of the plotting.



Near the center of the moon's disk this method of subdividing a map grid can be used, as explained in the text of this article.

We now come to the mapping technique, that is, the process of getting the photographic details into their correct map positions. Some compilers of recent lunar charts have not chosen to reveal their methods of doing this. Even the careful Fauth has appreciable positional errors in his general chart. Goodacre and Wilkins appear to have used a mixture of sketching and tracing from scaled photographs, and when this is added to copying from older maps the result is deplorable, in no way reflecting the high precision that is potential in any good lunar photograph.

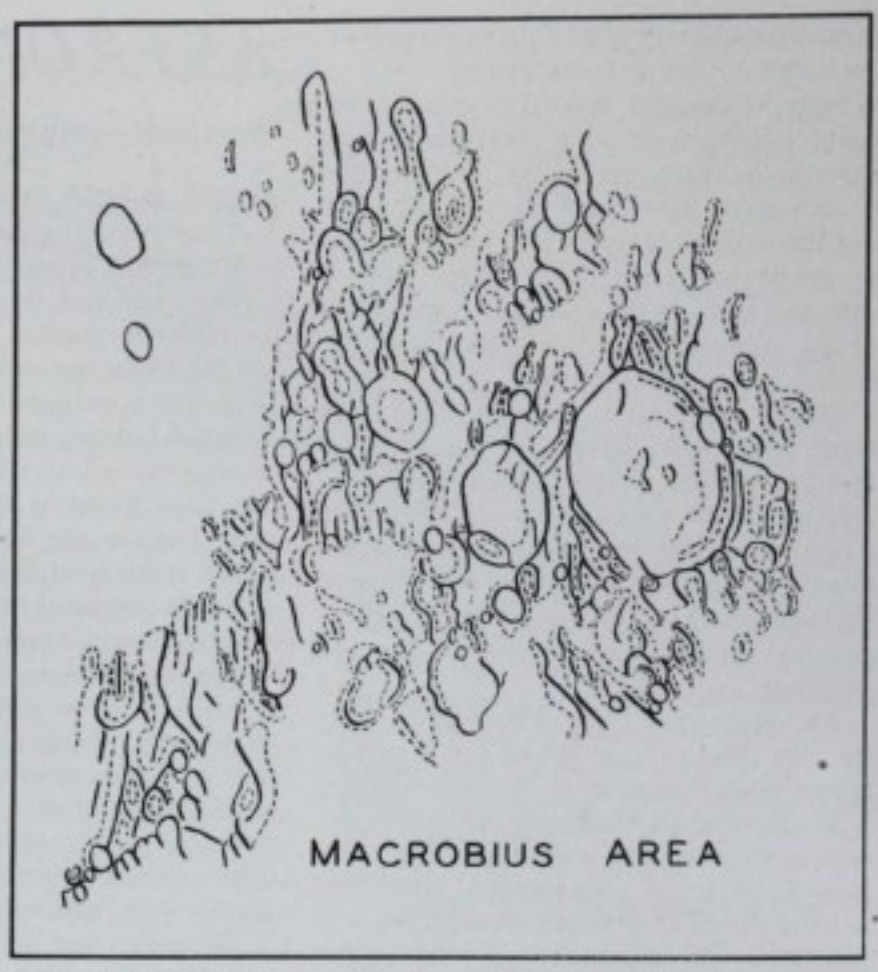
All better methods involve much hard work. In England, A. N. Neate measures all salient points on crests and bases of slopes, and computes the selenographic co-ordinates of these rigorously. The intervening short lines are then easily sketched in. This very accurate procedure is especially valuable for limb areas. Nearer the center of the disk, mapping difficulties are less severe, and here one can use the *distorted-grid* technique so familiar to cartographers.

The principle of this method is very simple. The intersections of the rectangular map grid occupy definite selenographic positions. The locations on the photograph of these grid intersections can be computed by any of several methods. Smooth curves are then ruled through the computed positions, and the grid is thus established on the photograph, with a square-by-square correspondence between photograph and map. The detail in each distorted square of the photograph can then be copied into the proper square of the map.

For accurate work, the squares should be small, certainly not more than $\frac{1}{4}$ inch at map scale. Since it is inconvenient to compute so dense a grid, a simple graphical procedure can be used to subdivide the squares of a coarser grid. Smooth diagonal curves are ruled through the grid intersections, and these intersect at points that locate another family of curves midway between the curves of the original grid. The process of subdivision may be repeated until the resulting grid is dense enough for accurate copying.

If a map projection which represents the moon's surface without foreshortening is desired, the photographs should be rectified to eliminate that effect, since otherwise the difficulties of interpretation and mapping become too great. At several institutions, projector-globe combinations have been used that give the approximate equivalent of a vertical view of any part of the moon's surface.

Interpretation of photographs into the lines and symbols of a map poses many problems. Certain small details will remain just outside the resolution of the photograph, while others will cause faint, dubious markings easily confused with



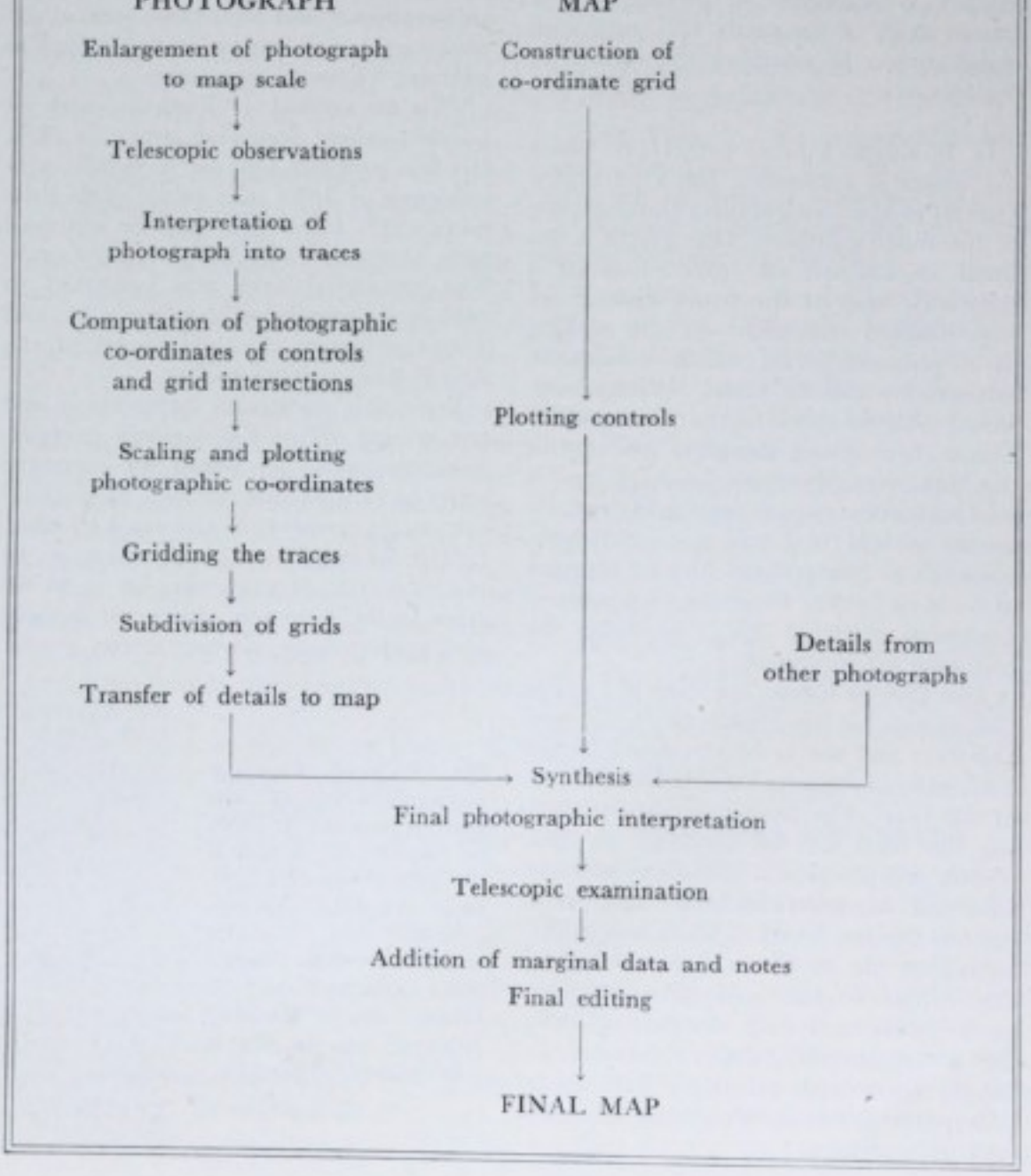
The region of the crater Macrobius. At the left is the area shown in G. P. Kuiper's "Photographic Lunar Atlas"; at the right is the author's interpretation trace. Both views correspond to morning illumination. Below is a schematic outline of the processes in making a new modern atlas of the moon.

defects. Clearly, the interpreter must have a certain amount of experience with visual observations of the moon, for only in this way can he become familiar with the difference between photographs and the much sharper visual image glimpsed at the best moments.

Recent researches indicate the existence on the moon of numerous families of fine parallel markings. The coarser of these are known to be groovelike valleys. In many areas, these families intersect and overlie each other, giving rise to extremely complex patterns, which present the interpreter with some difficult problems in delineation, since the real nature of these markings is still unknown.

Stereoscopic interpretation methods have been suggested for lunar photographs, but would not lead to a useful appreciation of relief. Even with maximum libration differences, it is easily calculated that a good stereoscopic observer would barely detect height differences of 2,000 feet. On the other hand, differences of a few score feet can be recognized monocularly, by exploiting oblique solar illumination and long shadows. Nevertheless, stereoscopy is useful in disentangling the very foreshortened details of limb regions, as E. A. Whitaker's experiments have shown.

When interpretation is being pushed to the limit, stereoscopy can be used to eliminate spurious markings. If two plates, taken within a minute of each other, are combined as a stereoscopic pair, the lunar landscape seems perfectly plane, but photographic defects appear to lie out of this plane. The slight visual discomfort



they cause then leads to their immediate detection.

Interpreters have tended to concentrate on photographs showing areas under very oblique lighting, yet views with steeper illumination have their uses. They filter out the shallow features and allow a grasp of the major relief. The golden rule of interpretation is the constant comparison of all available good photographs of the region under examination.

When everything possible has been done, there will still remain discrepancies and unresolved details which should be referred to the visual observer. The latter has an essential role, but his techniques must be highly systematic. Such check observations are best recorded on photographic enlargements prepared for the purpose.

Recent events in astronautics foreshadow the third period of lunar cartography by photography from space vehicles. The charting problems will then become very similar to those encountered in mapping from aerial photographs, and there is little doubt that lunar cartography will pass from the astronomer to the photogrammetrist. Precise stereocomparators and mathematical schemes already known will be used to triangulate the moon's surface in three dimensions, while the complex stereoscopic plotting machines, already so successful in producing contoured maps of the earth, will serve with equal success in mapping the surface of the moon.

G. P. Kuiper's lunar project, of which the writer is a member, has a particular interest in the triangulation and mapping of the moon's surface. Our group is too small to attempt the production of a large-scale map of the entire disk, so we have limited our effort to the making of a photo-map, on which subsequent cartography can be based. We have selected some 60 sheets of the *Photographic Lunar Atlas* giving complete coverage of the disk. On these we have plotted a standard orthographic map grid with intervals of 0.01 in ξ and η, so that positions can be interpolated with an accuracy of 0.001 or better. From the viewpoint of positional accuracy this is probably the best map yet produced.

The first 29 sheets, covering the entire disk except for the limb regions, are now complete and are to be published by the University of Arizona Press before the end of the year. The remaining sheets covering the limb will be available in 1961.

Our group works in close co-operation with the Aeronautical Chart and Information Center, which is the cartographic agency of the U. S. Air Force. Much of the computational and prepublication work for the new map was performed by the technicians of ACIC. In return, we supply them with telescopic data to be incorporated into their own lunar studies and publications.

ASTRONOMICAL SCRAPBOOK

Richard Carrington and a "Singular Appearance" on the Sun

ONE MAJOR DIFFERENCE between today's astronomy and that of a century ago has arisen from the greatly increased cost and complexity of the tools for research. Today, a 200-inch telescope can be built and effectively worked only by a great co-operative effort, with the financial backing of a wealthy foundation or a government. Then, an individual like Lord Rosse or William Lassell could erect and use the largest telescope in the world at his own expense.

In the England of the 1850's, amateur and professional were on much the same footing instrumentally, and many lines of research that we would regard as professional were being followed at a score of private observatories. Thus Lassell was cataloguing galaxies, J. R. Hind was discovering minor planets and computing comet orbits, Admiral Smyth and W. R. Dawes were measuring double stars, and J. Baxendall was detecting new variables.

Among the ablest in this group of English private astronomers was Richard C. Carrington (1826-75). Son of a well-to-do brewer, he began his astronomical career as an assistant at Durham University Observatory. There he mastered the skills of an astronomer, but after three years at the poorly equipped institution he decided to establish his own observatory.

This he erected at Redhill, south of London, where observing began in 1854. His first program was the formation of a catalogue of 3,735 stars north of declination +81°, whose positions he observed with a transit circle of 5-inch aperture. The completed work was published in 1857 at the expense of the Admiralty, and won Carrington the gold medal of the Royal Astronomical Society.

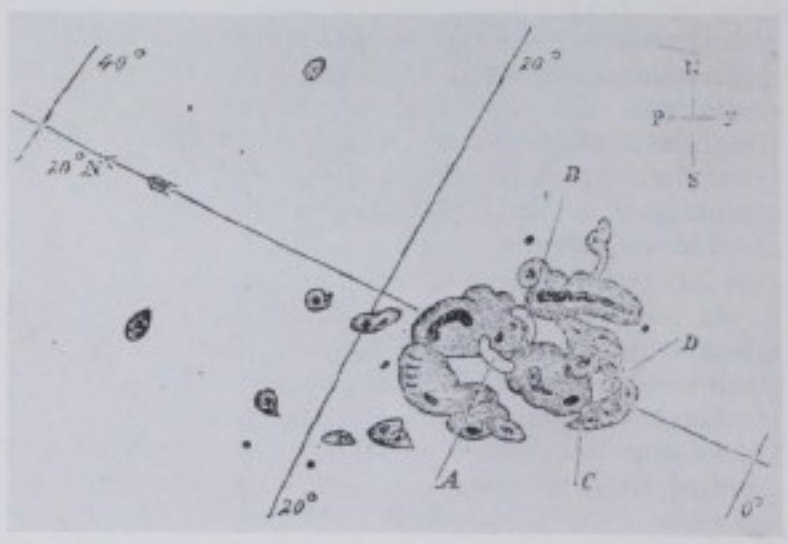
Even this enormous undertaking did not occupy all of Carrington's energies. Simultaneously, he began an intensive series of sunspot observations, to clear up the vexing problem of the sun's rotation. In the focus of his 4½-inch refractor, he placed a cross of gold wires set at 45 degrees to the direction of diurnal motion, and projected on a white screen a solar image 11 inches in diameter. With the telescope fixed, he allowed the sun to drift across the field, and the times of contact of the solar limbs and sunspots with the crosswires were recorded. In this way, Carrington could determine accurately the position of each spot with respect to the center of the disk.

Observations on this plan were made on every possible day from November, 1853, to March, 1861. Carrington's masterful analysis of the results, published in a large quarto volume, was a milestone in solar investigation. He determined first the orientation in space of the sun's axis of rotation, with such precision that his values remain standard today, and are still employed in the *American Ephemeris*. Next, he derived the solar rotation period for different heliographic latitudes, finding it to decrease markedly from the sun's equator toward its poles. This important discovery explained away many discrepancies among the less thorough rotation studies of earlier astronomers.

It was during the course of these observations that Carrington witnessed a remarkable event on the sun. On the morning of September 1, 1859, he had completed his routine drawing of the disk, and at 11:18 was timing the drifts of sunspots. Suddenly two intensely bright white patches appeared in a large spot group on the northern part of the sun. He wrote:

"My first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object-glass . . . [but by] causing the image to move by turning the R. A. handle, I saw I was an unprepared witness of a very different affair. I thereupon noted down the time by the chronometer, and seeing the outburst to be very rapidly on the increase, and being somewhat flurried by the surprise, I hastily ran to call some one to witness the exhibition with me, and on returning within 60 seconds, was mortified to find that it was already much changed and enfeebled."

(Continued on page 329)



On Richard Carrington's drawing of the sun, September 1, 1859, he marked by A and B the places where a brilliant eruption first appeared. Five minutes later, the flare faded from sight at C and D. From the "Monthly Notices" of the Royal Astronomical Society.

Amateur Astronomers

AAVSO Fall Meeting Held at Springfield

INTENSE observing activity and improved society finances were reported to members of the American Association of Variable Star Observers, at its 49th annual fall meeting held October 14-15 at Springfield, Massachusetts. The sessions took place in the museum of science, at the invitation of its director, Frank Korkosz.

During the past year, according to Mrs. Margaret W. Mayall, 58,791 brightness observations of variable stars were received from 234 persons, 46 per cent of the estimates coming from members outside the United States.

One of the principal contributors to this total was Cyrus Fernald, of Wilton, Maine. In a talk before the association, he described his experiences in passing from his first variable star observation, of R Leonis on May 2, 1937, to his 100,000th, of TY Cygni on June 27, 1960. Two other AAVSO members have reached this goal: Albert Jones of Timerau, New Zealand, and Reginald de Kock, Capetown, South Africa.

Treasurer Percy Witherell, Jamaica Plain, Massachusetts, announced that the AAVSO endowment fund contains securities now having a market value of over $100,000 — a long-time objective.

Among the highlights of the sessions for papers was Dr. Peter M. Millman's lecture on the co-ordinated radar and visual studies of meteors now underway at Ottawa. This large-scale program under the auspices of the National Research Council of Canada promises to yield greatly improved information about meteor rates. Other noteworthy presentations were the account of RW Aurigae variables by Miss Meredith Baldwin, Wellesley College, and color movies of solar prominences taken by Walter J. Semerau, Kenmore, New York.

Society officers elected for 1960-61 are Clinton Ford, Suffield, Connecticut, president and secretary; Dr. Dorrit Hoffleit, Maria Mitchell Observatory, first vice-president; and William Cleaver, New Haven, Connecticut, second vice-president. Mr. Witherell and Mrs. Mayall were re-elected treasurer and director, respectively.

The spring AAVSO meeting will be at Ottawa on May 26-27, 1961, and the 50th-anniversary meeting is scheduled for Harvard Observatory next October 13-14.

+++ Amateur Briefs +++

Juniors of the Brentwood, Tennessee, Astronomy Club have nearly finished their photoelectric photometer. The 10 members are being guided by Dr. Robert Hardie of Dyer Observatory.

The Kaiser Aluminum and Chemical Corp.'s plant at Mexico, Missouri, has built and presented to the Central Missouri Amateur Astronomers a mounting for the group's 12½-inch reflector.

Amateurs with two-way radio equipment may contact the radio communication section of the Montreal Centre of the Royal Astronomical Society of Canada by tuning in on the 75-meter phone band every Wednesday and Saturday evening. More information on the network is obtainable from David Sands, 4655 Cavendish Blvd., Montreal 28, Canada.

A woman's auxiliary, comprised of members' wives in the Lehigh Valley Amateur Astronomical Society of Allentown, Pennsylvania, has been set up to raise money for the building fund. Their planetarium project (Sky and Telescope, June, 1959, page 430) is almost completed.

The Miami Valley Astronomical Society in Dayton, Ohio, has obtained a turret-type gun mount that is being reworked into a mounting for the club's 12-inch telescope.

"Ignorance is bliss until you discover the truth," editorializes the October number of *Star Dust*, bulletin of the Astronomical Society of Harrisburg, Pennsylvania. "The editor's wife gave him a book, entitled *How To Make and Use a 6-inch Telescope*, that has a description of how to silver a mirror. Robert Thompson obtained the materials, and we spent a frustrating evening trying unsuccessfully to do the job. Our main trouble was carelessness in mixing the silver nitrate and ammonia, so we got more silver on the dish than on the mirror. But later the editor decided to read up on the subject in *Amateur Telescope Making — Book 1*, beginning on page 412, and he *then* discovered that the mixture we were using is known as fulminating silver and very explosive. A letter has been written the author, Patrick Moore, suggesting that future editions carry a note of caution."

The Junior Astronomical Society of Madison, Wisconsin, is the new name adopted by its members to avoid confusion of initials with another group in Indiana.

Open house at the Monte Sano Observatory of the Rocket City Astronomical Association in Huntsville, Alabama, is held on the Friday of or shortly after first-quarter moon. Visitors are welcome. Time: dark sky until 11 p.m.

The October *Asterisks*, bulletin of the Amateur Astronomers Association's instruction committee, contains an article on the moon illusion. While they last, free copies may be obtained by writing the committee chairman, Patrick Rizzo, 1881 61st St., Brooklyn 4, N. Y.

H. M. C.

AMATEUR ECLIPSE OBSERVERS INVITED TO CANNES

A letter has been received from the Société Astronomique de la Cote d'Azur offering to assist amateur astronomers from other countries who journey to Cannes, France, to observe the total eclipse of the sun this coming February 15th. Assistance will be provided in such matters as hotel accommodations and the selection of observing sites.

The nearest large city on the Mediterranean seacoast is Nice, which is shown on the map of the eclipse track published in the July issue, page 16. Cannes is situated about halfway from the center of the path of totality to its southern edge.

Further information can be obtained by sending a self-addressed envelope and an international postal reply coupon to Dr. Schmidl, President, Société Astronomique de la Cote d'Azur, 2 Rue Jonquière, Le Cannet par Cannes, Alpes-Maritimes, France.

THIS MONTH'S PROGRAMS

Baltimore, Md.: Baltimore Astronomical Society, 8 p.m., Enoch Pratt Free Library main building. December 19, Darius E. Sukhia, Martin Co., "Radio Astronomy."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. December 9, Dr. J. J. Nassau, Warner and Swasey Observatory, "Current Exploration of the Universe."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. December 7, William E. Shawcross, Sky and Telescope, "Bubbles in the Sky."

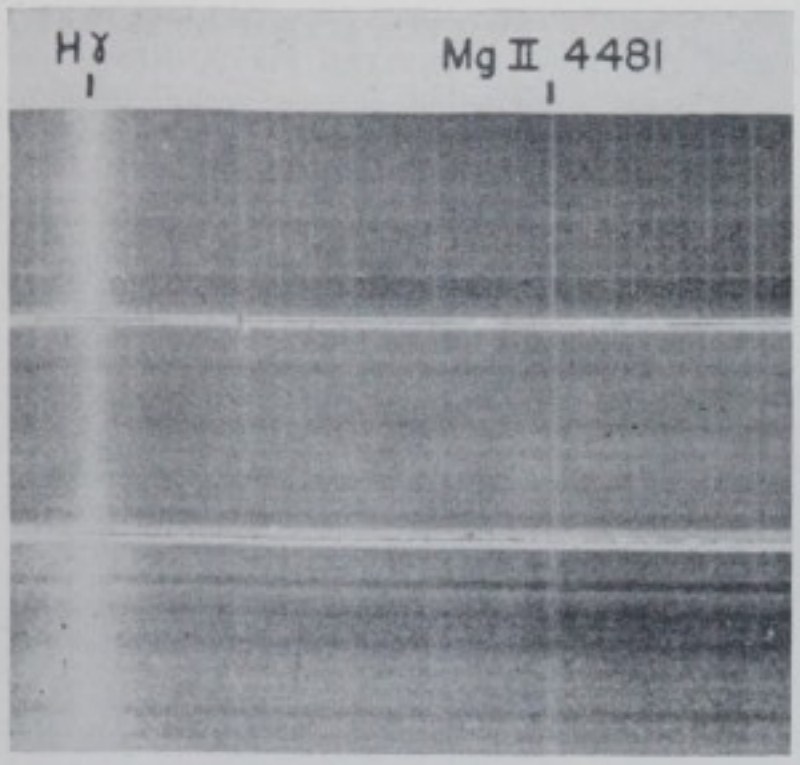
New York, N. Y.: Junior Astronomy Club, 8 p.m., Waverly building, New York University. December 16, Dr. Luigi G. Jacchia, Smithsonian Astrophysical Observatory, "What the Motion of Satellites Has Revealed."

Philadelphia, Pa.: Rittenhouse Astronomical Society, 8 p.m., Franklin Institute. December 9, Dr. Leendert Binnendijk, Flower and Cook Observatory, "Contact Binaries."

Plainfield, N. J.: Amateur Astronomers of Union County, 8 p.m., Stillman School auditorium. December 16, Dr. Robert Sells, Rutgers University, "Relativity and Space Travel."

NEW YORK OBSERVERS

The observing group of the Amateur Astronomers Association in New York City has been granted use of the Kada Observatory, located on the roof of the Fieldston School in the Riverdale section of the Bronx. The observatory can be reached by subway from all parts of the city, yet is far enough away from most smoke, lights, and skyscrapers to offer a darker sky and an unobstructed horizon.



Spectra of A2 stars Theta Leonis (top), Theta Andromedae, and Gamma Ceti, with projected equatorial rotations of 0, 125, and 195 kilometers per second, respectively. The 4481 line is broadest for Gamma Ceti.

Some Problems of Stellar Rotation — I

OTTO STRUVE, *National Radio Astronomy Observatory**

A GOOD EXAMPLE of how a new field of astronomy can arise from a spark of scientific imagination is provided by a pioneer paper on the interpretation of stellar spectra, written by the English astronomer Capt. W. Abney in 1877. If a star were rotating around an axis nearly at right angles to the line of sight, he asked, what observable changes would be produced in its spectrum?

Abney correctly pointed out that the observed spectrum is actually a composite of light from all portions of the star's disk. Because of the Doppler effect, wave lengths in the light of the receding edge of the star would be shifted toward the red, those from the approaching edge toward the violet. The net effect would be to broaden every line in the spectrum.

This idea found little favor among Abney's contemporaries, and H. C. Vogel in Germany attacked it because some stellar spectra contained both broad and narrow lines. Several decades had to elapse before a growing knowledge of spectroscopy enabled astronomers to list the many other factors that could widen spectral lines, and to learn how to distinguish rotational broadening. Observationally, the problem had also to wait for improved instrumentation.

The actual effect of stellar rotation is illustrated above, in the spectrograms of three *A*-type stars. The top one, Theta Leonis, has no observable rotation, and its magnesium line of 4481 angstroms wave length is sharp and narrow. For the second star, Theta Andromedae, the greater breadth of this line indicates a rotational speed at the star's equator of at least 125 kilometers per second. For the third star, Gamma Ceti, whose magnesium line is wider still, this speed is at least 195 kilometers per second.

In the case of an individual star, the direction of its rotational axis is unknown, and the measured speed of rotation is only a minimum value of the true equatorial velocity. Clearly, if the axis were tilted nearly toward the earth, the line broadening would be much less than if the same star were viewed with its axis perpendicular to the line of sight.

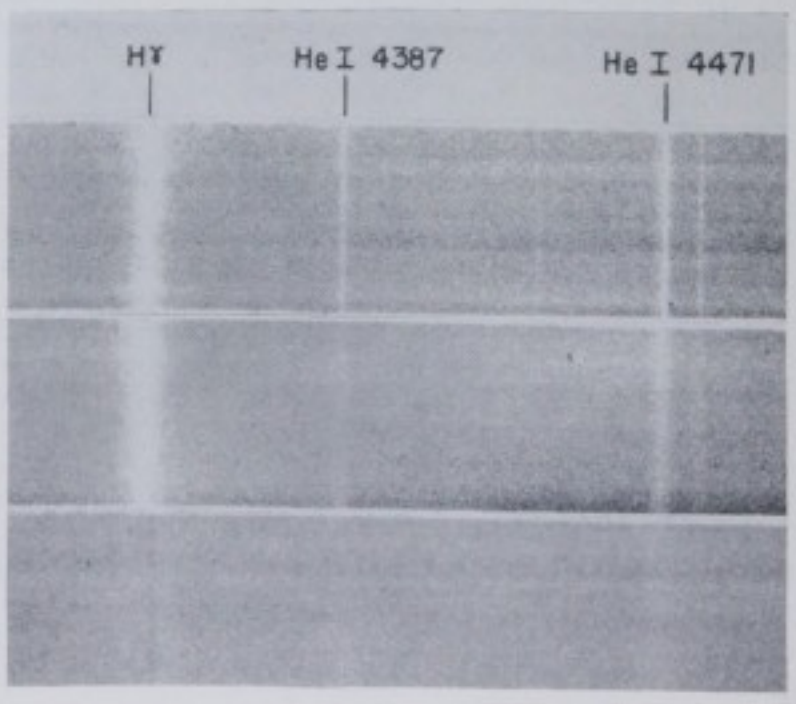
Fortunately, the rotational axes of the stars in general are probably randomly oriented. Hence, for a group of several dozen or more stars, it is possible to apply a statistical correction to their average observed rotation rate and thus find their true average rate, free from foreshortening effects.

Astronomers have known for almost 40 years that there are many stars in our Milky Way system that have rotation periods of only a few hours. Most of these fast-turning bodies, whose equatorial velocities may in exceptional cases be as great as 500 kilometers per second, belong to early spectral types — *O, B, A,* and early *F*. Single stars (those not members of binary systems) of the later spectral types, late *F, G, K, M, N, R,* and *S,* usually turn slowly. The sun belongs to this second group, because its rotation period is nearly one month, with an equatorial speed of only two kilometers per second.

The fastest rotations of all occur among some emission-line stars of spectral class *B*. In such a very rapidly spinning object, the centrifugal force at the equator approximately balances the gravitational force of the star, as has been pointed out by A. Slettebak and others. The equatorial layers of its atmosphere are highly unstable, and clouds of gas may escape to form a tenuous ring around the star.

Pleione, like some other rapidly rotating early-type stars in the Pleiades, has emission lines in its spectrum, and these have been explained as due to just such a gaseous ring. However, Pleione is not what astronomers call a zero-age main-sequence star; it has had time enough to convert much of its hydrogen into helium, thereby moving away from the main sequence in the H-R diagram toward the giant-star domain. It has long been a puzzle how such a star can now produce an equatorial ring, for it should have been smaller, and hence spinning faster, when on the main sequence. It would seem that Pleione should have relieved its instability long ago, and now be stable.

This paradox has been cleared up in an article published early this year by J. Crampin and F. Hoyle in the *Monthly Notices* of the Royal Astronomical Society. The two British astronomers show that the internal structure of a star undergoes a significant change during the tran-



Portions of spectrograms of the early B-type stars Iota Herculis (top), Eta Ursae Majoris, and HR 2142. They have projected equatorial rotations of 0, 210, and 450 kilometers per second, respectively. In the third case, the rapid rotation has broadened all the lines until they are almost obliterated. These spectra and those above are reproduced from the "Astrophysical Journal."

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

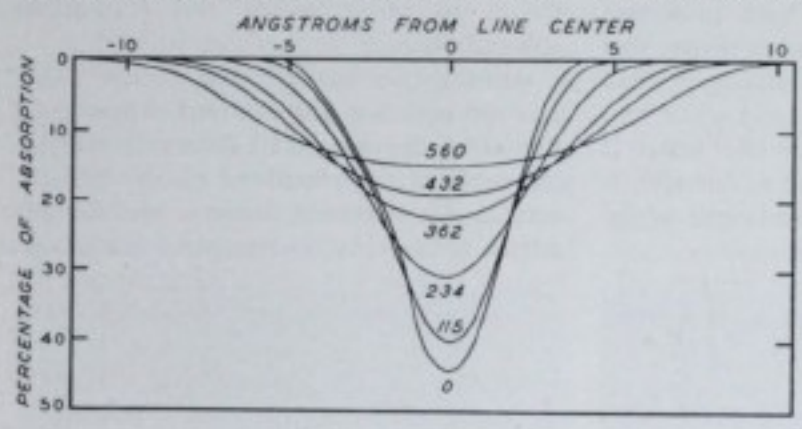
sition from the zero-age main sequence to the giant stage. A fairly dense isothermal core forms inside the star, causing its equatorial regions to become more sensitive to centrifugal forces. Thus, even though the rotation is slowing down, the increased sensitivity may allow new gaseous rings to form.

Crampin and Hoyle find that when an *A*- or *B*-type star on the main sequence ejects material from its equator, it soon becomes stable for an interval of some millions of years. Then a second, brief stage of ejection sets in, followed by more millions of years of stability, and the process repeats. In this way, the star can continue to shed rings of gas long after it has left the zero-age main sequence.

An important observational result concerning young stars is due mainly to the work of G. H. Herbig, at Lick Observatory, on T Tauri-type variables. As we have mentioned, normal main-sequence stars of late spectral type turn very slowly on their axes, but the T Tauri stars usually have broad absorption lines, indicating rotational velocities of the order of 50 or 100 kilometers per second. These variables seem to be single stars, and are believed to be very young. Still in the process of contraction, they have not yet reached the main sequence. Though such rotations are not exceptionally fast, and may not cause equatorial instability, they do suggest that very young stars often spin faster than those that have already arrived at the main sequence.

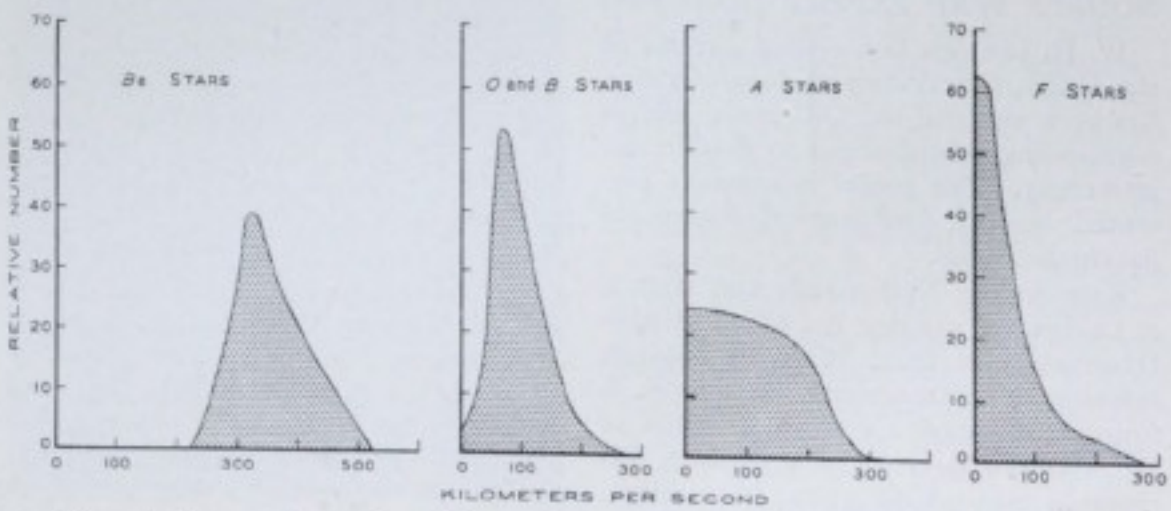
Consider, for example, a T Tauri star of spectral type *G*, with an equatorial rotation of 75 kilometers per second, in contrast to the two kilometers per second of a main-sequence *G* star like the sun. As the T Tauri variable contracts, it does not become a solar-type star. Instead, its evolutionary track in the H-R diagram carries its representative point leftward and slightly upward. Preserving angular momentum* while contracting, it may end up as an *A* or early *F* main-sequence star, whose rotational velocity could easily be around 200 kilometers per second. Hence, no contradiction is involved, at least for the present.

Among the bright Pleiades, shown with surrounding nebulosity in this Lick Observatory picture, are some of the most rapidly rotating stars known.



The deepest curve, labeled 0 kilometers per second, is for the 4026 helium line of Epsilon Cassiopeiae. The other curves are computed from it to show how increasing spin produces broadening. After A. Slettebak, from the "Astrophysical Journal."

Rotation is an important factor in the problem of star formation. A principal difficulty has been to explain how a vast diffuse cloud of gas and dust can ever contract into a star that has as little angular momentum as the 10^{53} units characteristic of a very rapidly spinning *A*- or *B*-type star. The whole solar system's angular momentum is only 3×10^{52} units. This stumbling block has been recognized for over a century in connection with P. S. Laplace's nebular hypothesis of the origin of the solar system. The famous French mathematician Henri Poincaré gave an illuminating account of the difficulty in his *Lecons sur les Hypothèses Cosmogoniques* (1913). There, on pages 84 to 86, he con-



The relative numbers of rapidly and slowly rotating stars are shown here for different spectral types. These curves, by K. H. Boehm, allow for varied axial orientations, so the abscissae are equatorial rotational velocities.

*Angular momentum is a measure of the quantity of rotation. For a mass point it is mvr, where m is the mass, v its velocity, and r its distance from the center of motion. For an extended body, such as a large cosmic dust cloud, the angular momentum is the sum of the values for all the individual particles. In this article, angular momenta are expressed in units of gram centimeter^2 per second.

siders the case of a cloud of particles, moving in random directions, which condense to form the solar system, as proposed by R. du Ligondès. As the particles combine, their angular momenta will tend to cancel out, because their motions are random.

Poincaré estimated the degree of cancellation of the angular momenta in the following manner. He imagines an initial cloud, 100,000 astronomical units in radius, all of whose particles move in the *same* direction, under the force of gravity of the cloud. The cloud's angular momentum is about 10^{55} units, according to formulas of celestial mechanics. This is about 30,000 greater than 3×10^{50}, the present angular momentum of the entire solar system. The value today, therefore, would result if there were a very slight tendency of the primordial swarm to rotate in a preferential direction.

A different way of looking at the problem of the low angular momenta of stars, compared with those of the interstellar clouds from which they condensed, is by a statistical theory like that W. H. McCrea developed to explain the origin of the solar system. His ideas were described in Sky and Telescope for January, 1960, page 154.

Suppose, again, the original cloud had a radius of 100,000 astronomical units, and consisted of separate cloudlets or condensations moving in random directions at one kilometer per second. The number of these cloudlets would be very great, and can be estimated from McCrea's formulas. If several have coalesced, then others colliding head on with them would contribute mass to the protostar while adding very little angular momentum. Other blobs that did not collide with the protostar would escape from the cloud, carrying off angular momentum. McCrea's calculations show that most of the original angular momentum can be removed in this way. But since the cancellation would not be complete, the resulting star should rotate at a relatively slow rate.

(To be continued)

DOUBLE STAR EXPERT HONORED

W. H. van den Bos, retired director of the Union Observatory at Johannesburg, has been awarded the Gill medal for his outstanding contributions to double star astronomy. This medal is annually presented by the Astronomical Society of Southern Africa.

Born in the Netherlands and trained at Leiden, Dr. van den Bos went to Union Observatory in 1925. With the 26½-inch refractor at Johannesburg, he and W. S. Finsen conducted a systematic search of the southern skies for new doubles, discovering about 3,500 pairs. In addition, he made many thousands of precise micrometer measures of known pairs, and calculated numerous binary star orbits.

NEWS NOTES

TWO VERY FAINT STARS

The earliest plates made with the 48-inch Schmidt telescope for the Palomar Observatory-National Geographic Sky Survey were taken a little more than a decade ago. They are now old enough that by repeating photography of the same areas changes in position of many stars should be revealed. With this in mind, W. J. Luyten, University of Minnesota, repeated five plates in the fall of 1958, as a guest investigator at Mount Wilson and Palomar Observatories, and in 1960 Milton L. Humason obtained one more plate.

To find which stars had moved against the general background of stars, Dr. Luyten placed the old and new plate of a pair in a blink comparator, recognizing fast-moving stars by their apparent jumping back and forth as he alternately viewed one plate and then the other. In all, on the six pairs of plates, some 1,100 stars showed appreciable proper motions.

Two of the most interesting of these may be the faintest star known and the faintest white dwarf. Dr. Luyten writes:

"A star, LP 464-53, at right ascension $0^h\ 17^m.0$, declination $+12°\ 38'$ (1950 coordinates), with a proper motion of one second of arc annually, shows faintly on the red plates — red magnitude about +20.2 — but is invisible on the blue plate of the Sky Survey pair. Probably it is a very faint red dwarf. Assuming that its photovisual magnitude is around 20.5, and its parallax of the order of 0.1 second of arc (roughly 30 light-years), its absolute magnitude is also +20.5. This, therefore, appears to be the least luminous star now known, fainter even than Van Biesbroeck's companion to BD +4° 4048 (absolute magnitude 19.3), and some two million times fainter than the sun. If seen from the same distance as our sun, it would be only one fourth as bright as the full moon.

"The second object, LP 321-98, is at $12^h\ 39^m.8$, $+30°\ 14'$ (1950), not far from the north galactic pole, and has a proper motion of 0.55 second annually. But while its photographic magnitude is +20.2, the photovisual magnitude is 19.5; hence its color is almost the same as that of the sun, and it seems to be a degenerate star or white dwarf. Again it is the faintest of its class, with an absolute magnitude around +18, or some 180,000 times fainter than the sun, and probably possessing a density of many tons per cubic inch."

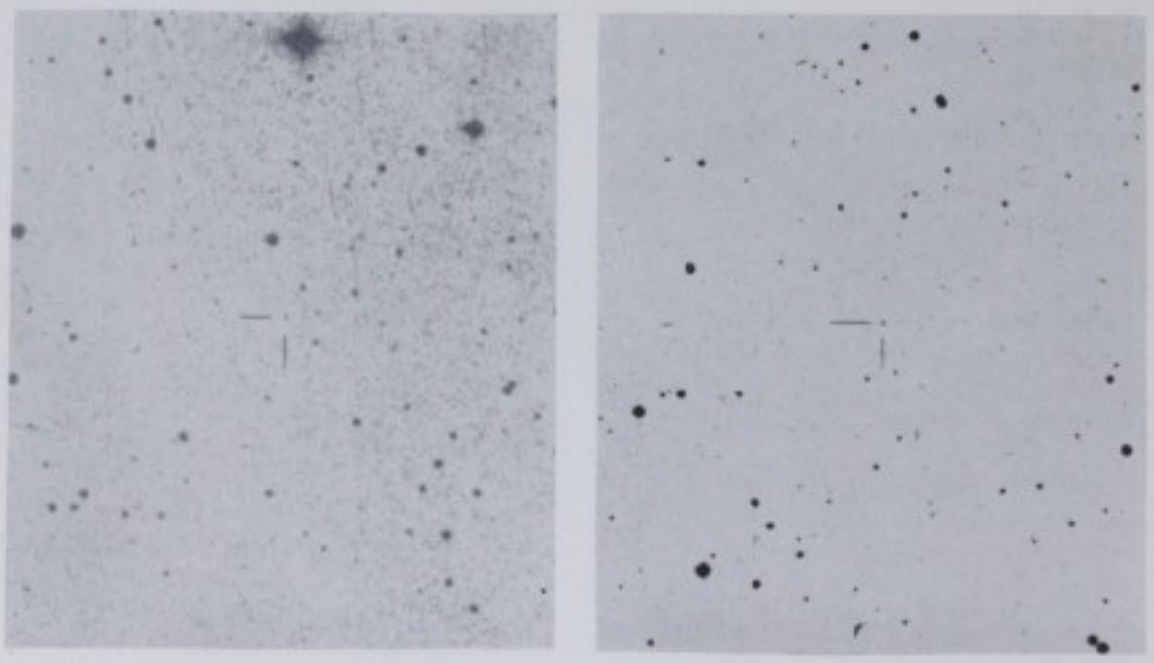
JULIE VINTER HANSEN

A prominent Danish astronomer who was well known in the United States, Julie Vinter Hansen, died on July 27th at the age of 70, during a vacation in Switzerland. She had just retired from the staff of Copenhagen Observatory, where she had worked since 1915.

Much of Miss Vinter Hansen's research was in celestial mechanics, one noteworthy contribution being a study of the motion of Periodic Comet Comas Sola. At the outbreak of World War II she was in the United States, and spent the war years at Lick Observatory, working on spectroscopic binary stars.

From 1947 until her death, she was in charge of the International Astronomical Union's information bureau, located at Copenhagen Observatory. Here she supervised the collection of information on comets, novae, and other recent discoveries, sending out telegrams and circulars to observatories and individual subscribers.

Among the honors Miss Vinter Hansen received was the Annie Cannon gold medal of the American Astronomical Society. She was president of the Scandinavian Astronomical Society, and Danish editor of *Nordisk Astronomisk Tidsskrift*.



These are negative prints from two Palomar 48-inch Schmidt photographs, marked by W. J. Luyten to show what may be the intrinsically faintest star known (left center), and the faintest white dwarf star (right center).

IN THE CURRENT JOURNALS

CLIMATIC CHANGES OF THE PAST AND PRESENT, by Erling Dorf, *American Scientist,* September, 1960. "In terms of the remote geologic past, however, today's climate is actually unusually cold. In fact, we are still living in a 'glacial age' compared to the much warmer conditions of 35 to 40 million years ago."

QUANTITATIVE TESTS OF THE LICK OBSERVATORY 120-INCH MIRROR, by N. U. Mayall and S. Vasilevskis, *Astronomical Journal,* June, 1960. "The actual form of the surface was the primary goal of the quantitative tests from the very beginning, and for this purpose the original Hartmann (1904) method was considerably modified and refined as the testing proceeded."

OUTER SPACE PHOTOGRAPHY FROM YOUR BACK YARD, by Henry Paul, *Modern Photography,* September, 1960. "Any 35mm camera with just a 50mm f/2 lens can do good exploration work on meteors, sputniks, Northern Lights or constellations."

PHOTOELECTRIC PHOTOMETRY IN ASTRONOMICAL STUDIES, by Frank Bradshaw Wood, *Science,* October 21, 1960. "Astronomical photoelectric photometry is some 50 years old, but the facet that concerns us here is . . . the modern phase — developments which cover little more than the past ten years."

PROJECT WESTFORD

A belt of millions of minute artificial satellites has been proposed as a system for long-distance communication by high-frequency radio. The particles would be metallic fibers or dipoles, each about half an inch long and a third the diameter of a human hair, placed in orbit several thousand miles above the earth's surface.

Radio waves transmitted to the belt would be scattered back to earth for reception, the transmitting and receiving antennas being trained on the same portion of the ring. In principle, this process of orbital scatter is similar to the techniques of ionospheric and tropospheric radio communications. With two such belts, one extending east-west over the equator and the other north-south over the poles, radio transmission could be established between any two points on the earth.

Full-scale planning for Project Westford (formerly known as Project Needles) is being carried out at the Lincoln Laboratory of Massachusetts Institute of Technology, by W. E. Morrow, Jr., who in 1958 developed the basic concept of orbital scatter with Harold Meyer of the Thompson-Ramo-Wooldridge Corp.

Mr. Morrow suggests that a rocket be used to place a container of the needles in orbit, where during a day's time a dispensing mechanism would gradually release the tiny bits of wire. Within one or two months, the fibers would spread out to form a continuous ring around the earth, with average separation from one another being about 1,000 feet. Such a tenuous belt, the Lincoln Laboratory physicist believes, would not adversely affect radio astronomy observations.

At the London meeting of the International Scientific Radio Union in September, where Mr. Morrow described his project, there were extended discussions of the possible side effects of the radio-reflecting belts. There seemed general agreement that the initial Westford experiment would be harmless to present-day radio astronomy. But alarm was expressed for the future, a feeling described by Dr. Frank D. Drake, of the National Radio Astronomy Observatory:

"Radio astronomers are concerned with what may happen *after* the first project is successful. The present experiment is just barely safe. The natural course of progress, in the event of a satisfactory experiment, is for thicker Westford belts to be launched, more frequency bands to be covered, and much stronger transmitters to be used with the belts. Any one of these actions would produce effects that would harm observations. A combination of them could result in regions of strong radio intensity all over the sky at nearly all useful frequencies, and would prevent us, by far, from utilizing the sensitivity offered by large antennas and the new receivers. This could very nearly limit radio astronomy knowledge to its present level."

QUESTIONS . . . FROM THE S+T MAILBAG

Q. What was the most recent comet bright enough to be seen in the daytime sky with the unaided eye?

A. Comet 1947n, visible briefly in the Southern Hemisphere.

Q. What is the smallest telescope with which the Horsehead nebula has been viewed?

A. This very difficult object near Zeta Orionis has been seen in a short-focus 6-inch refractor by Leslie Peltier, Delphos, Ohio. Even with that aperture, success probably requires excellent sky conditions and unusual observing skill.

Q. When will bright Comet Mrkos 1957d return?

A. In about 13,000 years, according to recent orbit calculations by G. Schrutka-Rechtenstamm, Vienna University Observatory. The orbit is a very elongated ellipse; at aphelion, Comet Mrkos is 28 times farther from the sun than Pluto is.

Q. Which of the 1st-magnitude stars are known to vary in brightness?

A. Betelgeuse and Antares have light changes large enough to be followed visually. In addition, photoelectric measurements have revealed small variations in Aldebaran, Rigel, Spica, and probably Deneb.

Q. What is the largest meteorite in a museum?

A. The Ahnighito, found in Greenland and now at the American Museum-Hayden Planetarium, New York City. This iron meteorite is nearly 11 feet long and weighs 34 tons. W. E. S.

ASTRONOMICAL SCRAPBOOK

(Continued from page 324)

The two bright patches faded out of sight five minutes after they were first seen, vanishing as two rapidly fading dots. During the interval they had moved from positions **A, B** to **C, D** on Carrington's drawing, reproduced on page 324. The scale of his picture is about 11 inches to the sun's diameter, so the large spot group has roughly Jupiter's extent.

Fortunately a second English amateur, R. Hodgson at Highgate, had at that time been watching the same part of the sun, with a 6-inch refractor and solar diagonal. His independent testimony tells of "a very brilliant star of light, much brighter than the sun's surface, most dazzling to the protected eye, illuminating the upper edges of the adjacent spots and streaks." Hodgson also gave the duration as five minutes, and noted that at about the same time a disturbance in the earth's magnetic field was recorded on the instruments at Kew Observatory. On the following nights, an intense auroral storm was witnessed in many parts of the world. As we now know, had radio been in use in the year 1859, a world-wide blackout of short-wave communications would have taken place.

To present-day solar astronomers, Carrington's "singular appearance" is famed as the first solar flare ever reported, and one of the very few "white flares" — those intense enough to be visible in white light. It was a decade before another solar eruption was recorded, and not until the turn of the century, when the sun's disk began to be regularly observed in hydrogen light, that the phenomenon became familiar. Up to the end of 1956, a total of 438 flares had been catalogued, and the event of September 1, 1859, is among the two dozen admitted to the extreme class of importance 3+.

Very recently, D. H. Menzel has interpreted Carrington's flare as an exceptionally brilliant loop prominence, seen projected on the sun's disk. The Harvard astronomer points out that if sufficient coronal material is trapped and compressed in the loop, it will shine as an ordinary flare, observable in red hydrogen light. In extreme cases, a white flare such as Carrington saw could result.

JOSEPH ASHBROOK

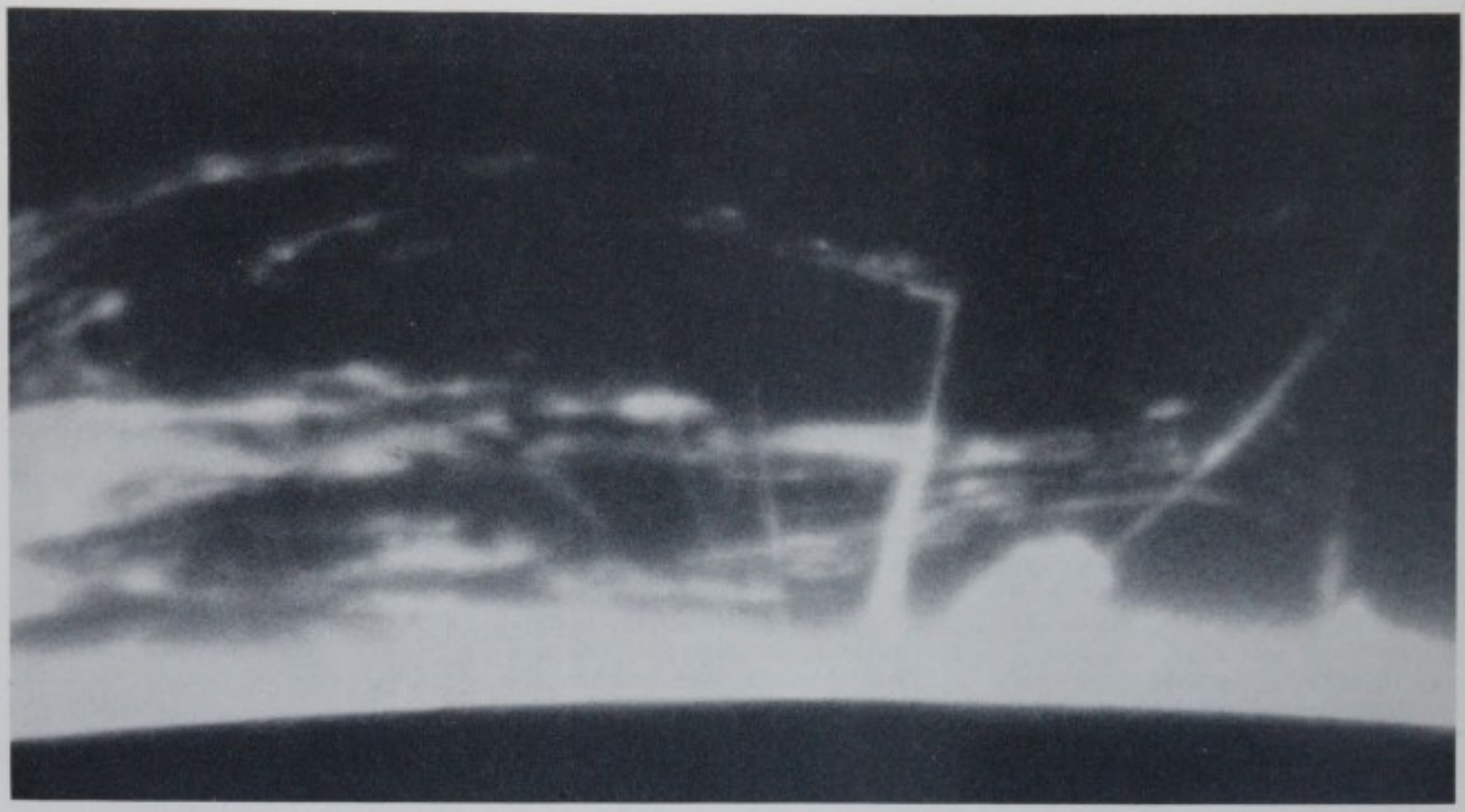


Fig. 9. The radial streamers, resembling searchlight beams, in this prominence photograph are a unique form of almost simultaneous surges associated with flares, classified by the authors as type BSs. The key to this June 24, 1958, photograph is given below. All the photographs with this article were taken at the Sacramento Peak Observatory in Sunspot, New Mexico, with the 6-inch coronagraph or the 15-inch prominence camera. Reproduced courtesy U. S. Air Force.

The Fine Structure of Solar Prominences—II

DONALD H. MENZEL and JOHN G. WOLBACH, *Harvard College Observatory*

LAST MONTH we discussed some of the basic forms of prominences observed in motion pictures taken in hydrogen-alpha light at Sacramento Peak Observatory. The intricate filamentary structure evident in a variety of prominences may be seen in the photographs accompanying this article.

The descriptive names in the Menzel-Evans classification, explained last month, refer basically to the appearance of the prominences. They provide a scheme for classifying them by form and, to a limited extent, by behavior. For example, the non-spot prominences tend to be long-lived, the spot types short-lived. The great majority of prominence forms are found to be class *A*, in which matter descends from the corona toward the sun's surface. Ascending (class *B*) prominences contribute only about 10 per cent of the total activity.

The classification is not intended to imply anything about physical conditions within the prominences. However, recent observations show that the categories may, in fact, be partially correlated with differences in physical conditions. H. Zirin and E. Tandberg-Hanssen suggest that material in the solar atmosphere falls into four classes, two of which pertain to prominences. The differences in the spectra of these classes indicate that in active sunspot prominences, such as surges and loops, the temperatures are substantially higher than they are in non-spot prominences. Estimates for the two groups are around 50,000° and 10,000° Kelvin. Although the two astronomers stress that these values probably do not apply to all the gas within a prominence, there appears little doubt that a significant difference in temperature exists between the two types. Much further observation and interpretation are needed to complete our understanding.

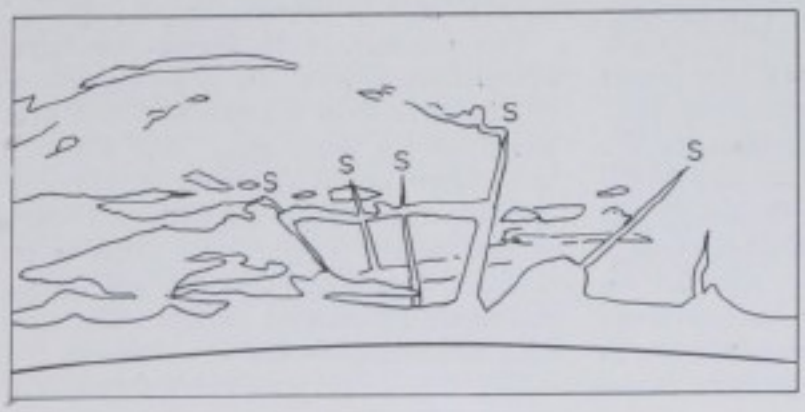


Fig. 9 (key). The surge prominences seen above are remarkable for the straightness and uniformity of the streamers, S, that seem to protrude radially from a point below the solar surface. At the left, matter flows from a disintegrating hedgerow, class A.

In terms of prominence behavior, more detailed activity is frequently observed than can be indicated by the division into ascending and descending types. Matter often escapes from a class *A* prominence in closely following knots, describing a graceful trajectory before cascading to the sun's surface (Fig. 9). Occasionally a rotary or spiraling motion occurs, and may be seen in puffs. Ascending hedgerows, such as those in Figs. 10 and 11, sometimes show rotation in either a horizontal or vertical plane. These varied activities often presage imminent disappearance of the object.

Non-spot down-flowing types (*AN*) exhibit complex structure. Essentially

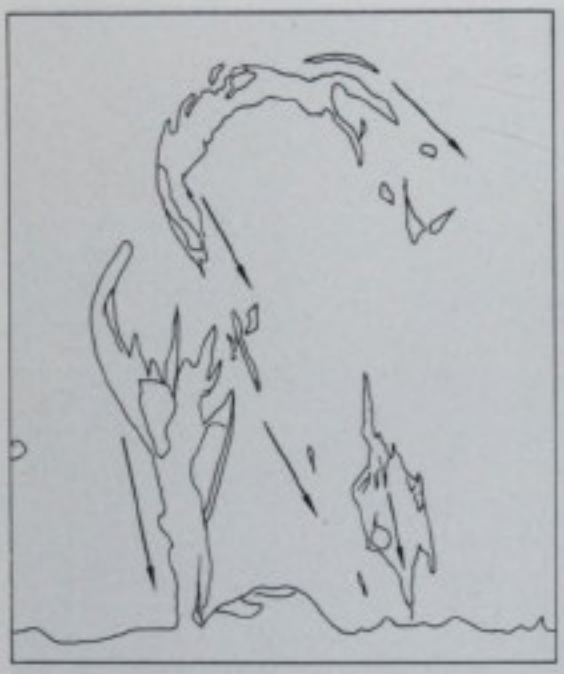


Fig. 10. A small ascending hedgerow is shown here. Little trace remains of the original complex structure. Arrows indicate the patterns of vigorous downward flow. Although this prominence is quite different from the loop in Fig. 14, similar motions are displayed, particularly in the downward flow along both sides of the arch. Recorded September 28, 1957, with the 15-inch prominence camera in New Mexico.

these consist of filamentary curtains extending upward 50,000 to 150,000 kilometers. The length over the sun's surface, usually greatly exceeding the height, ranges from 80,000 to as much as 700,000 kilometers. In contrast, the width or thickness is only about 5,000 kilometers. Since the curtain may touch the sun's surface at several points and display a fine structure of tangled and interwoven filaments, it presents the hedgerow appearance illustrated on page 254 last month.

The terms tree (*ANc*), tree trunk (*ANb*), and mound (*ANm*) may represent hedgerows whose lengths lie almost parallel to the line of sight. Tree and tree trunk may also apply to less complex hedgerows, while the more complicated ones appear to be built from these simpler forms. Hedgerows, particularly mounds and tree trunks, often change in appearance when a new sunspot group develops.

Suspended clouds (*ANf*) are similar curtains, shown in Fig. 12. They may be considered as hedgerows high above the solar surface. Observations continued for several days have shown that hedgerows often gradually ascend. This activity appears to be associated with the development or existence of a nearby sunspot group.

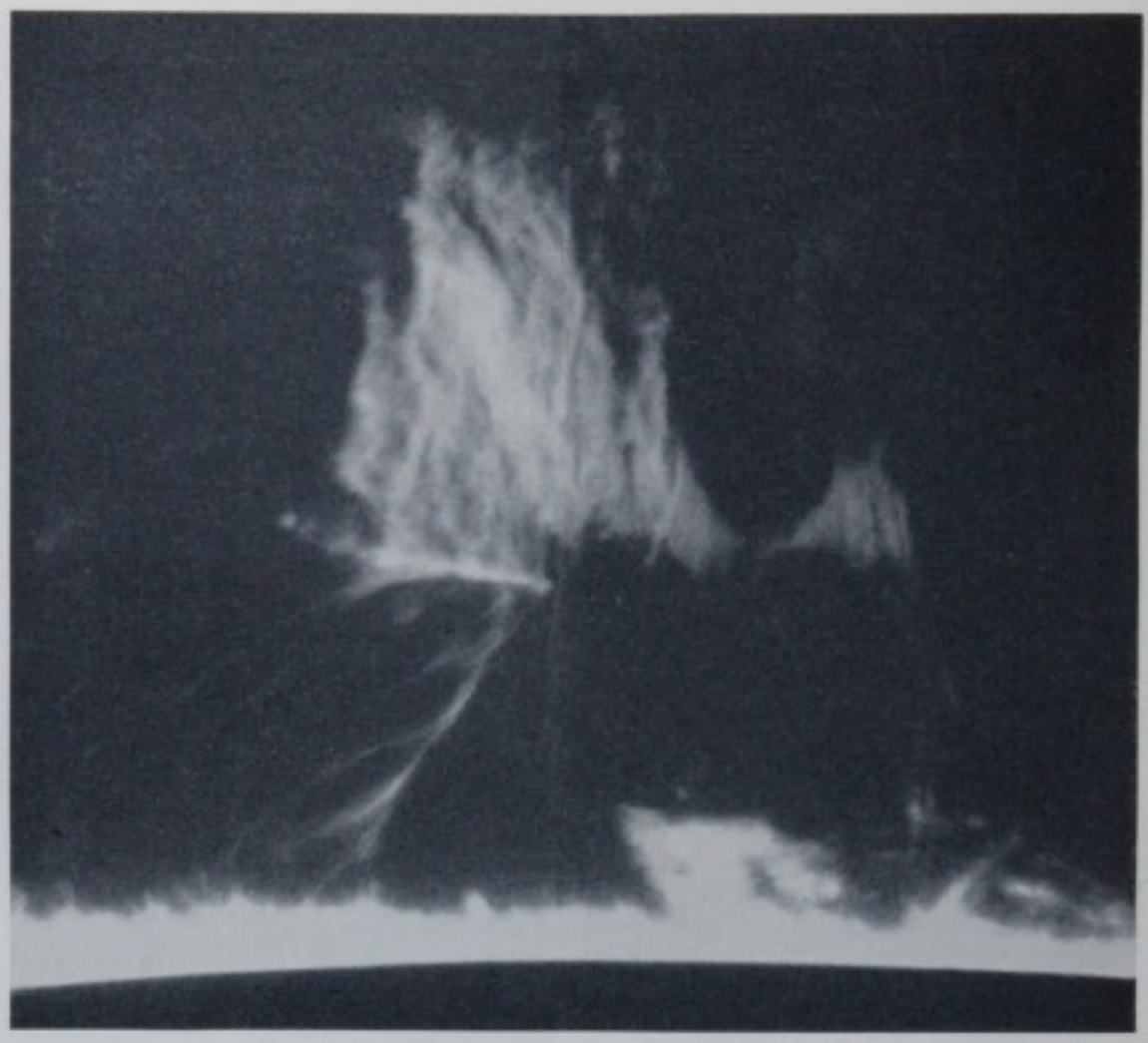
Coronal rain, type *ANa*, consists of streamers from regions in the corona, the moving matter becoming visible far above the sun. Occurring in a wide variety of luminosities, abundances, and rates of fall, rain is often seen close to simpler hedgerows, probably where the more complex structure is for some reason unable to develop. It too may persist for several days.

Most of the *AN* forms are connected with hedgerow development and tend to grow into the more complicated structures. These are semipermanent in shape and outline. Near their tops, luminous matter condenses from the corona and percolates slowly downward to the sun's surface, as described last month.

Funnels (*ASf*) differ from suspended clouds in that they originate over or in close association with sunspots. The descriptive name indicates that they are narrower at lower levels. They may appear as mere stationary knots from which rain starts to flow downward, or as more complex forms through which matter filters slowly before breaking out. In such

Fig. 11. This June 30, 1958, 15-inch camera picture shows a typical ascending hedgerow. The sharp, fine structure expands, fades, and may even disappear. Fishnet structure occurs at T. The ascension happened after the prominence had been visible for three days.

Fig. 12. The birdlike shape of this ANf-type prominence was recorded on October 2, 1957. Matter is breaking from the cloud at U and pouring downward in the direction of the arrow. Knots may be seen slanting across the filament at V. The sharp edge at the base of the cloud appears to be a consequence of the more complicated downward streaming above it. This cloud maintained its strange outline for two days, although the matter within it must have been renewed many times.



instances, their projected forms may suggest hedgerows. Not infrequently, they are found in a prominence-rich field of activity where hedgerows and sunspots exist in closely adjacent regions.

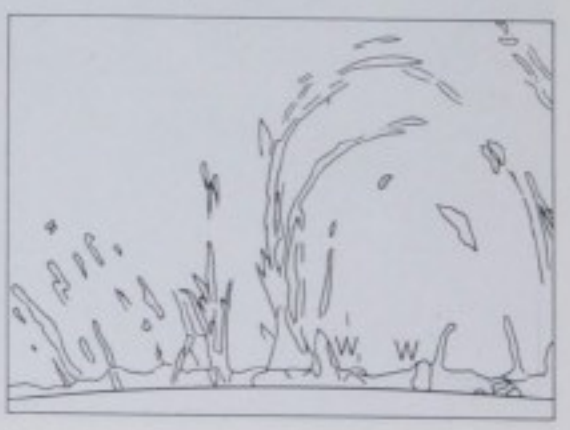
Loops (*ASl*) and rain (*ASa*) are observed to form over and near sunspots (Figs. 13 and 14), although coronal rain (*ANa*) is also seen in association with hedgerows, as we have already pointed out. Rapid changes in the magnetic fields of sunspots often make these associated prominences change radically in form from one day to the next. This is observable because the larger prominences may protrude above the edge of the sun for several days before rotation carries them away from the limb.

In both rain and loops, matter descends at between 100 and 200 kilometers per second; in less than half an hour the substance of these prominences must undergo a complete change. Sometimes funnels form over the regions where matter filters down, breaking through the lower boundary and cascading to the sun's surface.

Loops often occur suddenly and without warning. A loop commonly first appears as a brilliant knot, high above the solar surface. Then the luminosity grows downward, along two paths, giving the form of a loop. The brilliant filaments may reach great intensity, and then fade, resembling a string of sausages flowing downward, yet continuously replenished from some mysterious elevated source in the corona. A series of concentric loops sometimes forms, the later ones often much larger than the first, during the most active stage of the prominence.

The term spicule (*BNs*) refers to features in the chromosphere, a region above the sun's photosphere where the gas temperature begins to increase and the line spectrum changes from absorption to emission. The chromosphere is strikingly active and nonuniform. Its structure consists largely of small spikes about 10,000 kilometers high and 1,000 to 2,000 kilometers in diameter. Frequently spicules occur in pairs, or several may extend

Fig. 13. The remains of a loop (ASl) may be seen in this August 2, 1958, photograph of rain (type ASa). Part of the material came from funnel sources with well-developed complex structure. Surges, shown at W, occurred frequently during the several days of observation.



radially from a small mound, resembling the spines of a porcupine, as Richard B. Dunn and Sarah L. Lippincott have shown. A spicule swells and increases in height and becomes narrower at the base, disappearing after a lifetime of five to 10 minutes. Its activity resembles, on a small scale, that of a surge.

Prominences in which matter originates from below (class *B*) tend to have a brief existence. Figs. 15 and 16 illustrate surges (*BSs*), which occur in the vicinity of sunspots. A surge consists of filaments of matter rising upward with approximately uniform velocity. Observations indicate that the material has undergone an abrupt initial upward acceleration, 300 to 600 times as great as the acceleration produced by terrestrial gravity and 10 to 20 times that of solar gravity. Surge velocities range from 300 to 600 kilometers per second, with the first material ejected generally attaining the highest speeds.

The column, on reaching maximum height, usually stops and reverses its motion. The lower part may even start to return to the sun's surface while the top is still rising. A typical ascent lasts about 15 minutes, with matter falling back for about an hour thereafter. Surges sometimes recur along the original path.

Ejection of puffs (*BSp*) is a further form of surge activity. An individual puff is a knot of luminous material ejected at surge velocities. The knot, upon reaching its maximum height, fades and disappears or falls back to the surface. Repeated ejections of puffs are sometimes observed at active spot regions.

Flares, although not in the classification, should also be mentioned here. They are sudden brightenings of limited areas, in the light of hydrogen, occurring near sunspots on the disk. Their lifetimes are usually a few minutes, although exceptionally large flares may remain visible for several hours. Flares and surges are often closely associated, as illustrated by Figs. 9 and 16. Actually, some flares may be extremely bright surges in the early stage of development, retaining flare brightness only while they are close to the photosphere. Flares appear to be correlated with changes in the force fields around sunspots. The details of this relation, however, are not well understood, and provide one of the most important problems for future observational and theoretical investigation.

Fig. 14. These are the same loops as in Fig. 1, photographed June 28, 1957. The arrows show typical downward flow. At the left, descending threads brighten at similar heights.

Surges associated with flaring may exhibit a characteristic spraylike appearance. On other occasions, they may appear as uniformly luminous spikes (Fig. 9). Extreme surge velocities, exceeding 1,000 kilometers per second, have been observed. The largest flares, frequently followed within one to three days by severe disturbances of the earth's magnetic field and brilliant auroral displays, are the most violent form of solar activity observed.

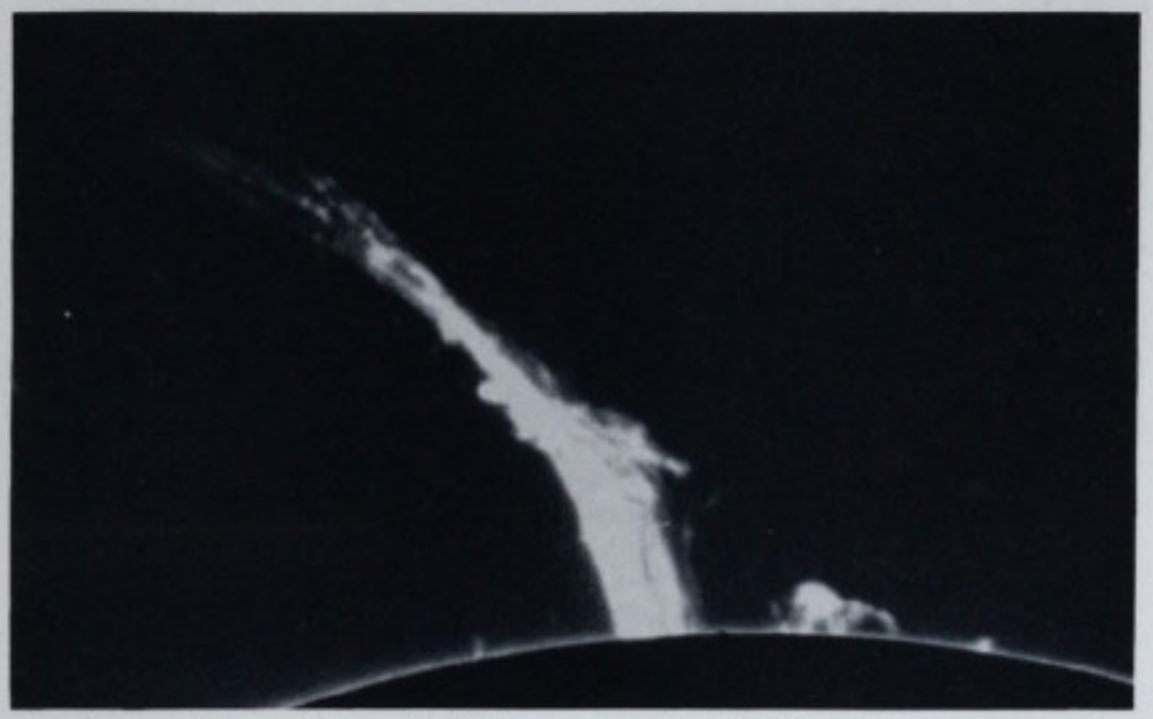


Fig. 15. A type BSs prominence, this violent surge lasted for about 15 minutes on May 25, 1951, its debris slowly settling during the next hour. At the top, bright knots tend to lie along lines perpendicular to the direction of motion (arrow).

The observations discussed here were obtained at Sacramento Peak Observatory, Sunspot, New Mexico, and are the result of research sponsored by contracts with the Air Force Command and Control Development Division. The authors are especially indebted to Mr. Dunn for the illustrative material for this article.

Fig. 16. This unusual prominence was part of a flare occurring on August 28, 1956. Matter streamed out of the sun at X and then reversed itself on reaching Y, falling back toward the right along curved trajectories.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 106th meeting of the American Astronomical Society at Mexico City, August 22-25, 1960. Complete abstracts will appear in the Astronomical Journal.

Report on Supernovae

An international search for supernovae in distant galaxies was described in a paper by F. Zwicky, M. L. Humason, and H. S. Gates, of Mount Wilson and Palomar Observatories. Participating in the program in addition to Palomar are the Steward Observatory at Tucson, Arizona, and the observatories in Berne, Switzerland, and Meudon, France. Funds for the survey have been made available by the National Science Foundation and the Swiss National Science Fund.

A first search for supernovae was conducted by Dr. Zwicky and J. J. Johnson with the 18-inch Palomar Schmidt telescope during the five years preceding World War II. They found 19 objects, among them the brightest supernova ever observed, in the dwarf spiral galaxy IC 4182. At its maximum brightness, this star was more than a billion times as luminous as the sun.

As a result of the present survey, which began in 1954, the number of supernovae detected has been raised to 44. Of these, about 15 were discovered during the past two years by Dr. Humason with the 48-inch Schmidt telescope.

Several classes of supernovae have been found, with their absolute luminosities ranging from 10 million to over a billion suns. The light curves of the different classes are not alike. Each type of supernovae has its characteristic spectra, bearing no apparent resemblance to the spectra of common novae. In spite of concerted efforts by observers and theoreticians alike, supernovae spectra have not yet been satisfactorily interpreted.

Fritz Zwicky was photographed by David Tellez as he spoke before the Mexico City meeting last August.

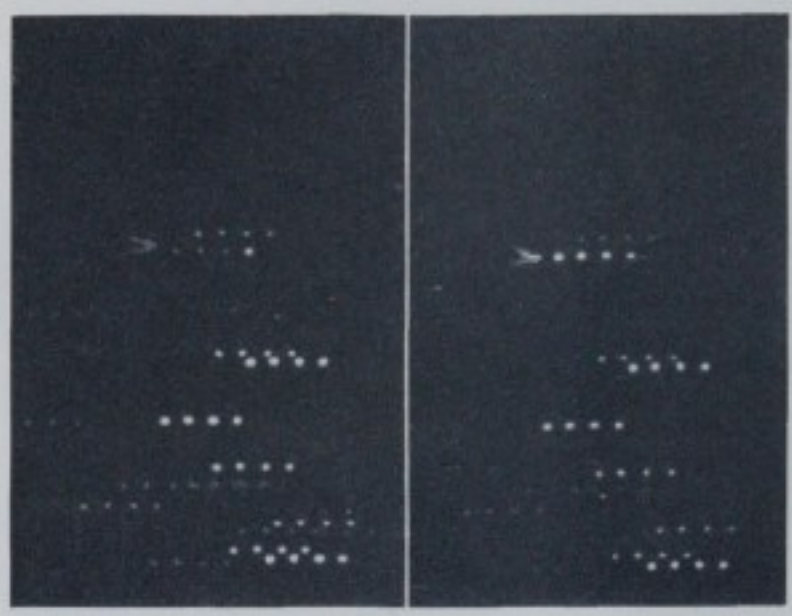
In presenting the paper, Dr. Zwicky pointed out that some of the bright galaxies may have supernovae occurrences at a much higher rate than the average of one every 300 years. For instance, in each of the spirals NGC 3184, 4321, and 6946, three supernovae have appeared in the past 60 years. And according to the number of remnants of probable old supernovae found in the Milky Way by radio astronomers, our own system would also seem to have a high frequency.

Because of their extremely great luminosities, supernovae can help us determine the distance scale of the universe, which is very poorly known. Dr. Zwicky described preliminary work on supernovae of type I in the relatively nearby Virgo cluster of galaxies. Seven of these stars had an average maximum apparent photographic magnitude of +11.6. On the assumption that they were not materially more luminous than the supernova of the year 1054, which gave rise to the Crab nebula, the distance of the Virgo cluster comes out about 20 million light-years.

This distance value, taken together with the red shift in the spectra of the Virgo galaxies, indicates a velocity of expansion for the universe (the "Hubble constant") of 175 kilometers per second for each million parsecs of distance from the sun. This is a higher value than indicated by other recent investigations. Applying it to the case of the most remote observed cluster, Cl 1410 + 5224 in Bootes (SKY AND TELESCOPE, August, 1960, page 80), whose velocity of recession is nearly half the speed of light, Dr. Zwicky obtains a distance of some 2½ billion light-years. If the Hubble constant is smaller than 175, the distance is greater, and other estimates for this cluster place it up to six billion light-years from us.

Flare Stars in Orion

The 27-inch Schmidt telescope of Tonantzintla Observatory in Mexico has been used by G. Haro, E. Chavira, and E. Mendoza in a search for flare stars in the neighborhood of the Orion nebula. With ultraviolet- or blue-sensitive plates, 601 exposures were obtained in 110 hours of observing time. In addition, 302 infrared exposures were made in 90 hours. This survey covered about 25 square degrees centered on the Trapezium cluster.



With faint arrowheads G. Haro has marked an Orion flare star on consecutive Schmidt camera plates. Each star image is a 10-minute exposure, and about four minutes elapsed between the two pictures. The star is faint in the first three exposures in the left-hand photograph, but brighter in the fourth. It had increased even more by the time the second plate was started, then began to decline. Tonantzintla Observatory photographs.

In this area, on the blue and ultraviolet plates, 55 new stars have been found that undergo rapid changes in light and spectral features. Some stars took as little as 40 minutes, others as much as 260, to go from normal minimum to maximum light and back to minimum again; the average time was about 108 minutes. The amplitudes ranged from 0.7 to more than four magnitudes, but there was no good correlation between amplitude and duration of outburst. On the average, at least once every two hours a stellar flare appeared in the region that was studied.

The Mexican astronomers found that the distribution of these flare stars in and around the Orion nebula is very much like that of T Tauri stars already known there. In fact, a number of the new stars appear to be typical T Tauri variables. Others are pure flare-type objects that during most of the time remain at minimum light and then can hardly be distinguished from normal late-type dwarf stars. Such is the case with UV Ceti and other flare stars in the neighborhood of the sun. This second group forms the

great majority of rapid variables found in the Tonantzintla survey.

When at minimum, the Orion flare stars have photographic magnitudes from 14.5 to fainter than 21.5. If they are considered to be at the same distance as the bright stars of Orion and the associated nebulosities, their absolute magnitudes range from +6 to fainter than +13, which is typical of red dwarf stars.

On the infrared plates, not a single flare star was found — at least none that changed in brightness by 0.2 magnitude or more. But many T Tauri stars showed conspicuous irregular variations. These infrared results support the belief that flare phenomena are produced by some kind of nonthermal process, which is mainly responsible for the ultraviolet continuous emission that appears during the flares, causing the star to brighten at short wave lengths but not at long ones.

Astrometric Reflector

A 60-inch reflecting telescope of novel design is planned for the U. S. Naval Observatory's station at Flagstaff, Arizona. The primary purpose of the new instrument will be very precise positional observations of faint stars by photography for the determination of parallaxes and proper motions. There is an urgent need for such studies of stars fainter than magnitude 13.5, which is about the limit of the long-focus refractors now used. Existing large reflectors, like the 200-inch at Palomar, do not have the extreme optical and mechanical stability required for astrometric work of the highest precision.

K. A. Strand, director of the Naval Observatory's astrometry and astrophysics division, described some design features of the proposed telescope, whose 50-foot focal length will provide a plate scale of 13 seconds of arc per millimeter. Light from the primary mirror is returned up the tube to a 36-inch-diameter flat, which reflects the converging cone of light through a 24-inch perforation in the primary. This folded optical system was chosen to insure utmost optical stability.

Both mirrors will be mounted more rigidly than is customary in conventional instruments. To reduce thermal distortion, the 2,200-pound primary and the 450-pound secondary will be made of fused silica, whose coefficient of thermal expansion is only a sixth that of low-expansion glass. The primary will be 10 inches thick, the secondary 5½. The main mirror is to be paraboloidal, with focusing done at the equipment platform on the rear side of its cell. A Ross zero-power corrector will be provided to eliminate coma and quadruple the area of the telescope's field for searches, but it will not be used for high-precision work.

To provide maximum efficiency in operation, the new 60-inch reflector will have provision for automatic photoelectric guiding. The present engineering design also includes automatic exposure timing and automatic plate transport.

The approximate exposure time for an 18th-magnitude star will be about eight minutes. In the central 22-by-22 minutes of arc of the field, star images will be measurable with a precision of ±0.04 second of arc — corresponding to only 0.003 millimeter on the plate.

In July, 1960, Congress appropriated $1,900,000 for construction of the telescope and its circular building, with a dome 65 feet in diameter. The instrument itself will be set 41 feet above the ground. Construction contracts are being let by the Navy's Bureau of Yards and Docks, with technical direction being provided by the Naval Observatory. The building will be placed not far from the present site of the 40-inch reflector at the Flagstaff station, some five miles west of the town at an elevation of 7,600 feet (SKY AND TELESCOPE, November, 1956, page 4).

Ground for the new installation will be broken next April. The fused silica blanks are being made at Corning Glass Works. The mirrors and other optics will be figured by Davidson Optronics, while C. W. Jones, Los Angeles, California, is the architectural and engineering contractor.

Photographic Star Atlas

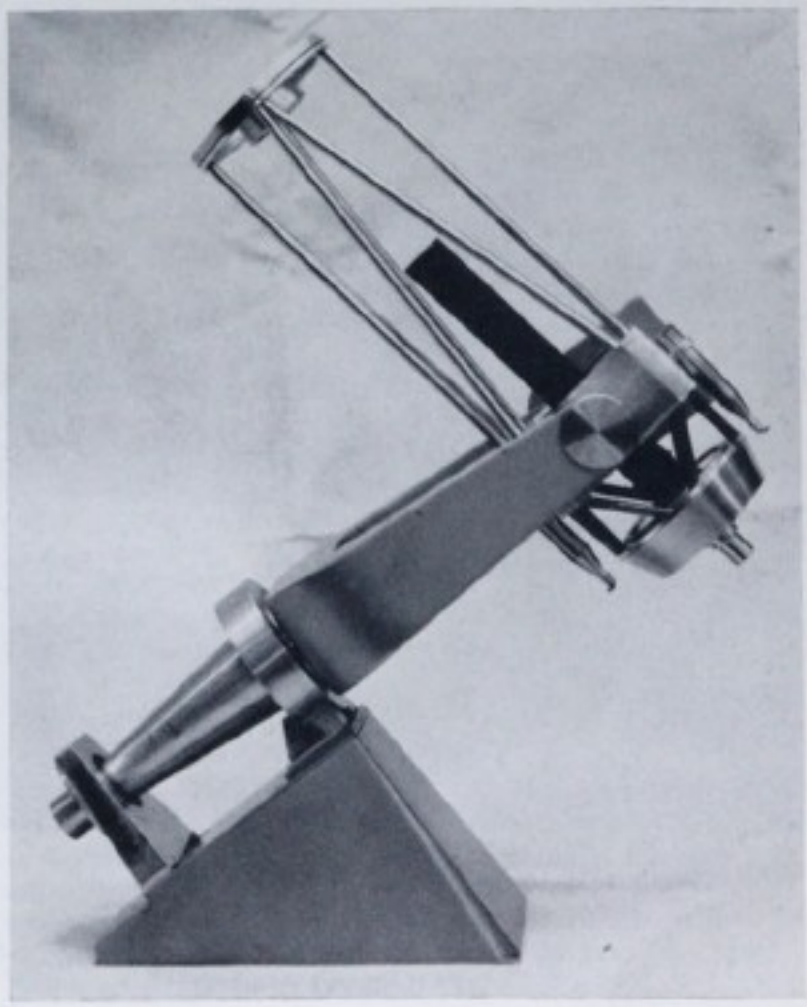
A new star atlas is being constructed by the Cartographic Institute of Ohio State University for the National Space Surveillance Control Center. It was described by A. Brandenberger and H. B. Wackernagel, and originated from a proposal by G. Miczaika to the Air Force Cambridge Research Laboratories.

Primarily, the atlas is to provide a means for quickly determining the position of an artificial satellite on film exposed in a Baker-Nunn satellite tracking camera, with an accuracy of about one minute of arc. The basic chart photographs were taken, therefore, by Baker-Nunn cameras in California and Chile, covering the entire sky in sections measuring 30 by five degrees. Each of the 212 sheets in the atlas is 15 degrees square, made up of nine five-degree pieces cut from the Baker-Nunn films. A coordinate grid for epoch 1950.0 is superimposed on the resulting mosaic, thus producing a star chart on the gnomonic projection, in which great circles are straight lines.

The scale of the atlas corresponds to a focal length near 50 centimeters. The first edition's charts will be mounted between glass for use in special blink microscopes at the camera stations of the Smithsonian Astrophysical Observatory and elsewhere. A second edition to twice the scale may be published at a later date, for it would serve many other astronomical observing projects, such as searching for comets.

AMERICAN ASTRONAUTICAL SOCIETY MEETING

The seventh annual meeting of the American Astronautical Society will be held January 16-18, 1961, at the Sheraton-Dallas Hotel, Dallas, Texas. Session chairmen include Thomas Gold, Samuel Herrick, Homer Newell, Fred Singer, and Otto Struve. Further information about the meeting may be had from the general chairman, J. W. Roach, Vought Astronautics, Box 1401, Grand Prairie, Tex.



In this small model are shown the sturdy fork-type mounting and skeleton tube of the U. S. Naval Observatory's astrometric reflector. The arrangement is Cassegrainian in appearance, but the 35-inch secondary mirror is flat. It obstructs about a third of the incoming light, acting only to fold the beam back on itself and shorten the tube length between mirrors to less than 24 feet. The long black tube is a typical Cassegrainian sky baffle, to cut out unwanted light; it fits over the perforation in the main mirror, which is contained in the tapered cell at the right. The angle of the polar axis to the horizontal is 35.2 degrees, corresponding to the latitude of Flagstaff. Official U. S. Navy photograph.

OBSERVING THE SATELLITES

Communications Satellites

BROADLY SPEAKING, there are two ways in which artificial satellites can be used in long-range radio communications. Echo I demonstrated the feasibility of the *passive* reflection of radio signals from one ground station to another. In an *active* communications satellite such as Courier I-B, whose October 4th launching was mentioned here last month, the signals are received and retransmitted.

The Courier system was developed by the Signal Research and Development Laboratory, U. S. Army Signal Corps, to handle the equivalent of perhaps 3.4 million words per day, with a 90-per-cent probability of one year's useful service. The prototype model, I-B, was built by Philco Corp. into a 51-inch sphere, the total assembly weighing about 500 pounds. It was launched from Cape Canaveral by a Thor-Able-Star vehicle, under the auspices of the Air Force's ballistic missile division.

To achieve long service life, Courier I-B carries much duplicate equipment — nearly half of its components are replacements that can be switched into the system on ground command. There are two ground stations, at Ft. Monmouth, New Jersey, and near Ponce, Puerto Rico, each with a 28-foot parabolic antenna.

When operations are to begin, one antenna is aimed at the point on the horizon where the satellite is expected to rise. Courier carries two tracking beacons, each weighing only six ounces and radiating some 50 milliwatts of power at 107.97 megacycles. As soon as one of these beacons is detected by the antenna, the ground station transmits a 135-megacycle coded command signal, which is picked up by one of the two Courier receivers. The signal is decoded and, if in proper form, the communications components are switched on, and the satellite acknowledges the command through an ultrahigh-frequency signal.

Transmission of messages to and from the satellite is at frequencies of about 2,000 megacycles. For incoming information there are four FM receivers, connected in pairs to two oppositely placed antennas. Since the satellite is spinning about 40 revolutions per minute, the output of each receiver changes continuously. The four outputs are combined in such a way as to obtain an optimum signal-to-noise ratio, and the information is recorded digitally on one of four high-speed tape recorders, or on a fifth recorder for voice or analogue data.

Simultaneously, Courier's four ultrahigh-frequency transmitters send stored data to ground. They are used in pairs, one for each antenna. Save for their output tubes, which radiate seven watts, these transmitters employ solid-state circuitry. Their combined 104-pound weight accounts for more than a third of the payload.

At the ground antenna, parametric amplifiers synthesize both phase and frequency coherence of the signals from the two satellite antennas, in spite of variations imposed by satellite spin and scintillation of the ionosphere. The ground receiving equipment automatically keeps the antenna properly aimed, as it feeds the extracted information into high-speed tape recorders. Later, the record is played back at lower speed, operating a paper-tape perforator which is fed to a teletypewriter that reproduces the information originally sent to the satellite by the reverse of this process.

Power for Courier comes from 19,152 tiny solar cells, each covered by an interference filter, and connected in dual arrays to parallel sets of nickel-cadmium storage cells. The functioning of the power supply is among one of the 26 properties of the satellite regularly reported by telemetry through a pair of 108-megacycle transmitters.

The input and output of the Courier satellite system are so great that 20 commercial teletype machines, operating continuously at 100 words a minute, would not overload its capacity. With four ground stations around the globe, a single satellite should be able to handle the Army's bulk traffic needs. Most of the communications to be carried are of low priority, comprising routine administrative and logistic matters. Such traffic is fast overburdening existing facilities, rendering them less capable of handling high-priority warning and command messages.

An obvious limitation in communicating by Courier between very distant points is the delay while the satellite travels with the message in storage; *real-time* communication is possible only if both stations are simultaneously in line-of-sight range. Hence the Advanced Research Projects Agency is developing the Advent satellite, which would circle the earth once in 24 hours at a height of some 22,300 miles, remaining stationary over a point on the earth's equator. Three such communications satellites, spaced equally around the world, would permit real-time communications over the entire globe, except for small areas near the poles. This idea was originally proposed in 1945 by A. C. Clarke. Even with present technology, the problems of placing an Advent satellite in orbit and controlling its motion are formidable.

Because of the complexity of active systems, passive communications satellites

A technician holds half of the Courier I-B spherical shell, which is made of epoxy fiberglass. Wooden mock-ups in the left background were used to determine the exact locations of the 38 instrument packages making up the payload. The assembled model then underwent a long series of rigorous tests. Photograph courtesy Philco Corp.

have an advantage, even though they require much larger antennas at the ground stations. Many designs are variants of NASA's 100-foot Echo I balloon. Major difficulties with such an inflated structure are extending the lifetime and preserving shape and rigidity. Another passive system is Project Westford (see page 329), in which a belt of millions of tiny reflecting needles are to be placed in orbit around the earth.

NASA is interested in the development of active satellites. Recently this agency announced a policy of providing launching facilities, vehicles, and tracking to private industry at cost, in order to aid establishment of commercial satellite communication systems.

Pioneer V and the Scale of the Solar System

THE interplanetary probe launched March 11, 1960, under the auspices of the National Aeronautics and Space Administration, has turned out to be of unusual astronomical significance, for observations of this object, 1960α, have been used to test a novel and promising method of calibrating the solar system distance scale. The first results were reported to the American Astronomical Society in August by J. B. McGuire, D. D. Morrison, and L. Wong of Space Technology Laboratories.

Communication with Pioneer V was maintained for 107 days while the probe traveled more than 170 million miles along its orbit, between those of the earth and Venus. It was a detailed study of this motion that gave the means of a re-evaluation of the astronomical unit — the mean distance of the earth from the sun.

Early in its trajectory, the probe was specially tracked by helical antennas at Cape Canaveral and at Singapore, while at Hilo, Hawaii, and Jodrell Bank, England, similar arrays were supplemented by parabolic antennas, 60 and 250 feet in diameter, respectively. The probe quickly outdistanced the helical antennas, and from March 13th onward was tracked only by the paraboloids.

Between May 8th and 21st, the 150-watt transmitter of 1960α was operated by ground command on several occasions, but deterioration of the nickel-cadmium storage batteries that accumulated energy from the solar cells brought these transmissions to an end, and only the five-watt transmitter could be used.

On May 24th, the Hawaiian station received its last signal from the probe, but Jodrell Bank maintained contact until June 26th, the final transmission leaving Pioneer V at 11:31:20 Universal time, at a distance of about 22,462,115 miles according to Space Technology Laboratories scientists.

The tracking program was aimed at precision measurements of the line-of-sight velocity of Pioneer V, by means of the Doppler shift in radio frequency. Each of the chief tracking stations was provided with a highly stable oscillator, controlled by a quartz crystal, to generate a 402-megacycle carrier signal beamed to Pioneer V. When Jodrell Bank was commanding the probe, the antenna radiated 10 kilowatts of power.

A four-pound transistorized receiver aboard the probe operated continually, its frequency range being automatically swept until tuned to the command signal. Then the probe locked onto the received frequency as long as the transmission continued. The 402-megacycle carrier was modulated by a 512-cycle tone, and this was digitally coded to command the functions of the probe, including switching on its transmitters.

The probe then rebroadcast the signal through the same antenna, but at exactly 16/17 the received frequency. This offset in frequency permitted probe and Earth station to communicate with a single antenna each; both were provided with diplexer units, to prevent the receiver from being swamped by the transmitter attached to the same antenna. The diplexer at Jodrell Bank allowed the 250-foot dish to receive signals as weak as 10^{-19} watt at 378 megacycles while transmitting 10,000 watts at 402 megacycles!

The signal received on the ground was compared with one obtained directly from the original oscillator, likewise coherently offset to 16/17 of the 402-megacycle frequency. In this way the Doppler shift could be measured — the change in frequency resulting from the relative velocity of Pioneer V and the ground station. The shift could be obtained with a precision of about one cycle per second — better than had been anticipated. In all, the probe was interrogated for 138.9 hours during the 107 days its signals could be heard. At the end of this interval, the weak returning signals, often obscured by noise, were taking four minutes for their long round trip through interplanetary space.

During the early part of the flight, the radial velocity of the probe was determined at one-second intervals, but at extreme range minute-by-minute averages had to be taken. The observed relative velocity decreased gradually to a low of 2.4 kilometers per second on April 6th, but had risen to 8.3 when the signals ended.

The way the Doppler data were reduced was kindly explained to the writer by E. R. Spangler, Space Technology Laboratories, in advance of publication. The observed frequency shift was first corrected for the daily motion of the antenna around the earth's axis, and for the monthly motion of the earth around the center of gravity of the earth-moon system. This gave the observed radial velocity for a particular moment, it being assumed that radio waves travel at 299,792.5 kilometers per second in interplanetary space.

Next, a precise ephemeris of Pioneer was calculated. The probe's motion could be computed from step to step by taking into account the gravitational attractions of the sun and all the planets from Mercury to Jupiter. Then the observed and predicted radial velocities were compared, and a least-squares calculation was made to determine the ratio of mass of Sun to mass of Earth that gave the best fit to the observations. From this ratio the length of the astronomical unit could be deduced. This study gave it as 92.9251 ±0.0085 million miles.

Astronomers usually express the size of the earth's orbit in terms of the solar parallax — the angle subtended by the earth's equatorial radius, as seen from the mean distance of the sun. The Space Technology Laboratories result gives the solar parallax as 8.7974 ± 0.0008 seconds of arc.

This new value agrees well with the 8.7984 ± 0.0004 derived by E. Rabe in 1950, from the mass of the sun as found by optical observations of Eros. However, it disagrees strongly with the 8.8021 ± 0.0001 obtained from radar observations of Venus in 1958 (Sky and Telescope, May, 1959, page 384, and July, 1960, page 13), and the 8.803 ± 0.001 that resulted from classical astronomical determinations of 1889 to 1924. Moreover, all of these values of the solar parallax are significantly larger than H. Spencer Jones' 8.790 ± 0.001, obtained from world-wide observations of Eros in 1931.

It is disconcerting that these and other solar parallax determinations, all based on immense labor, should differ by amounts considerably greater than the stated uncertainties. For nearly every practical need of the astronomer, the 8.80 seconds adopted for ephemeris purposes by international agreement remains adequate. However, for astronautical applications, especially space navigation, the astronomical unit must be known much more accurately.

When contact between Pioneer V and the earth was lost, the probe had completed only about a third of one revolution around the sun. This method for evaluating the sun's distance would give a greatly improved result if, for a future interplanetary probe, the Doppler observations could be extended over a larger part of a complete revolution.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

CORRECTION

On page 200 of the October, 1960, issue, the launching time of artificial satellite Echo I should read 9:39:43 UT, instead of 8:39:43. This editing error was pointed out by J. H. Respler, New York City.

Lick 120-inch Photographs—VI

LEFT: A region of dense dust clouds in Orion, about 1,500 light-years away, photographed in red light with Lick Observatory's new 120-inch reflector. The bright patch near the top is the nebula NGC 1999, consisting of dust illuminated by an imbedded star, with a dark foreground obscuration superimposed. In the lower part of the picture is one of the mysterious Herbig-Haro objects — a compact group of tiny nebulous knots, enlarged 2½ times in the inset. The arrows indicate two blobs of hot gas that appeared in this object in 1952, and that may represent an early stage in the formation of stars. Since that time, they have shown no further change. Another Herbig-Haro object appears as a bright, irregular marking above the left corner of the inset. This feature has been studied with the 200-inch Palomar telescope, by G. Haro and R. Minkowski, who reported to the American Astronomical Society in August. It, too, consists of small condensations on a faint background of unresolved nebulosity. These condensations range in magnitude from 18.4 to 21.5, and appear to have individual masses less than 1/10,000 the sun's mass. The scale of the main picture is 56 seconds of arc per inch. George H. Herbig took this 30-minute exposure on December 6, 1959, using a 103a-E2 plate.

TOP RIGHT: This delicate tracery of wisps of luminous gas forms NGC 6992, the northeastern part of the great Veil nebula loop in Cygnus. N. U. Mayall made this 30-minute exposure on a 103a-O plate June 26, 1960. Another Mayall photograph taken that night, showing the western part of the Cygnus loop, appeared on page 137 of the September issue. In this reproduction, one inch corresponds to 3.5 minutes of arc.

BOTTOM RIGHT: This remarkable clump of six galaxies in Serpens is known as Seyfert's Sextet, having been discovered in 1951 by C. K. Seyfert. The brightest member is the 15th-magnitude spiral NGC 6027, detected visually many years ago by H. Stephan with a 31-inch reflector. The three faintest members are of magnitude 17. Several of the sextet show tidal deformations, indicating their closeness to one another. These photographs and the one on page 340 are courtesy Lick Observatory.

The wreath of nebulosity at the top of this field is NGC 6888, which was discovered visually by Sir William Herschel over 150 years ago. Situated in a very rich star field of the Milky Way in Cygnus, NGC 6888 has a right ascension of $20^h\ 10^m.7$, declination $+38°\ 16'$ (1950 co-ordinates), not far from P Cygni. This nebula shines because it is near a very hot 7th-magnitude star, of spectral type O, whose ultraviolet radiation excites the gas to fluoresce. The entire field is streaked with faint nebulous wisps. N. U. Mayall used the Lick Observatory 120-inch reflector on June 24, 1960, for this half-hour exposure on a 103a-O plate without a filter. This is a 2.6-times enlargement from the original plate, on which the scale is 13.5 seconds of arc per millimeter.

OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

Visual Observations of the September Lunar Eclipse

MANY READERS of this magazine have reported visual observations made during the total eclipse of the moon on September 5th, besides sending in numerous photographs, of which a selection was published on page 256 last month.

Throughout North America, the lunar eclipse was an after-midnight spectacle, cut short by moonset in the United States except in the western parts. California, with its many amateur astronomers, was particularly favored, and clear skies generally prevailed there.

The September eclipse was a darker-than-average one, most watchers agreed. One way to rate the darkness of the eclipsed moon is by A. Danjon's five-point scale, explained on page 229 of the February, 1960, issue. On this scale, $L = 0$ indicates a very dark eclipse, the moon being nearly invisible; $L = 4$ means a very bright copper-red or orange eclipse. Of the 13 brightness estimates made within a few minutes of mid-totality, the average was 1.8, all ratings falling in the range between $L = 0$ and 3.

During totality, the central part of the earth's shadow appeared gray, with a tinge of red, to Eddie Ries, who used a 6-inch reflector at Pico Rivera, California. This color description is typical of those by observers with telescopes. The outer portion of the umbral shadow was a brighter red, especially noticeable near the beginning and ending of totality. To naked-eye watchers, the whole lunar disk generally appeared a deep coppery red.

In keeping with the darkness of the eclipse, little detail could be viewed on the moon during totality. Ben Levine, Los Angeles, California, noted that his 3-inch refractor showed all the seas but no craters, while to the unaided eye only vague dark patches were visible. At Las Cruces, New Mexico, the maria remained visible throughout totality to Gordon Solberg, in both 8 x 30 binoculars and a 2.4-inch refractor. Terrill Isbell, at El Paso, Texas, remarked on the invisibility of craters in 7 x 50 binoculars. In a 4-inch reflector, 46x, Craig L. Johnson of Boulder, Colorado, could see Menelaus, Manilius, Copernicus, Kepler, and Aristarchus throughout the total stage.

The most remarkable feature of this eclipse was a dark band crossing the moon, reported by many observers a little before mid-totality. Mr. Johnson's log reads: "10:44 Universal time: Dark east-west lane crossing entire moon centrally. Width is ⅓ lunar diameter. 7 x 50 binoculars. 10:55 UT: Dark lane moving south. 10:59 UT: Dark lane becoming more prominent. 11:19 UT: Dark umbral core very prominent; its northern edge

Clyde E. Honstein, Jr., El Paso, Texas, took this picture of the eclipse at 9:55 Universal time, 19 minutes after first umbral contact. North is at the top. He used a 4¼-inch reflector of 24 inches focus and a 22-mm. eyepiece. A 35-mm. single-lens reflex camera with a 50-mm. Tessar lens was held at the eyepiece, the iris being fully opened to f/2.8. This was Dr. Honstein's first astronomical photograph.

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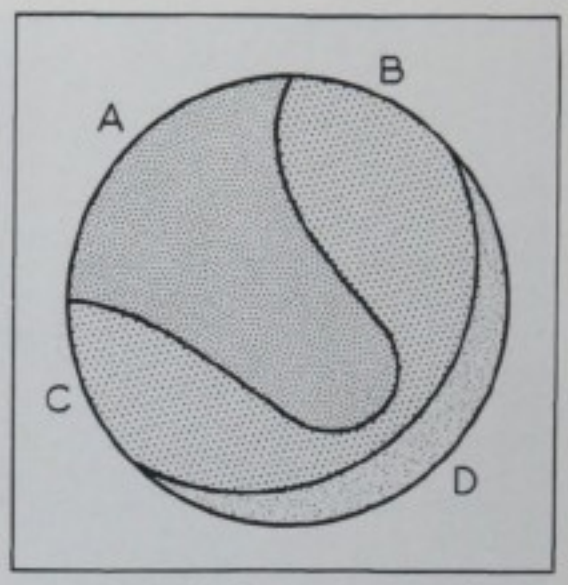


The dark band across the eclipsed moon is labeled A in this sketch, made at 10:50 Universal time by John Elk, III, Ponca City, Oklahoma, who observed with 3x opera glasses. Area B was coppery; C, dull copper; and D, relatively bright.

corresponds to the northern edge of the dark lane."

The reality of this abnormal appearance is confirmed by the records made at Yallourn, Victoria, Australia, by T. B. Tregaskis, who worked with a 6-inch reflector. "10:53 UT: A dark belt about 700 miles wide extends across the moon from east to west. It was later reported to me by three other observers." The belt was not to be seen 32 minutes later.

Dr. M. Lattey, at Vernon, British Columbia, saw this same dark band from 11:00 to 11:15 UT, and remarked that the areas north and south of it were very dull red. Using a 6-inch reflector, Ron Dyvig, Deadwood, South Dakota, noted the dark band at 10:55 UT. The accompanying sketch by John Elk, III, Ponca City, Oklahoma, shows its appearance in opera glasses a few minutes earlier.

These observations indicate a temporary anomaly in the distribution of light within the earth's shadow. It is quite distinct from the fact that the southern half of the moon was somewhat darker than the northern, easily explained by the moon passing a little north of the umbra's center.

A number of amateur astronomers made special observations of the outer shadow or penumbra of the earth. At San Jose, California, four members of the San Mateo Astronomical Society timed the initial visibility of the penumbra to the unaided eye and in binoculars as 36 minutes before first umbral contact. The same group, reports Richard T. Johnston, found that the visible breadth of the penumbra at the time of first contact was between 20 and 25 per cent of the moon's diameter.

As pointed out on page 474 of the June, 1960, issue, accurate timings of the contacts of lunar eclipses, and of the entrances of craters into the umbra and their exits, have scientific usefulness. They can be utilized in evaluating the enlargement of the earth's umbra, which seems

to change from one eclipse to the next.

The observed UT of each contact, and the number of timings (in parentheses), are: Contact I, 9:35:47 (3); II, 10:38:03 (8); III, 12:05:05 (2); and IV, 13:06:28 (2). For second contact, the mean error of the average is ±10 seconds.

Tabulated here are the results from 121 crater timings, in the form of the averages for individual events. In each case, the time is the moment when the shadow edge appeared to touch the center of the crater. A small proportion of the observations have not been used – those made in heavy haze, those referring only to one edge of a crater, and a few very discordant times that may be errors of record. Only the times for specific points on the moon, whose co-ordinates can be ascertained, are utilizable, hence timings of maria have been omitted.

ENTRANCE INTO UMBRA

Crater or Mountain	*UT*	*No.*
Grimaldi	9:37.8	5
Schickard	9:41.0	2
Letronne	9:42.3	1
Gassendi	9:43.3	3
Lichtenberg	9:47.2	1
Kepler	9:48.9	5
Aristarchus	9:52.5	5
Pitatus	9:52.6	1
Tycho	9:53.4	8
Euler	9:55.1	1
Copernicus	9:56.5	6
Pytheas	9:59.6	2
Ptolemaeus	10:00.7	1
Eratosthenes	10:02.6	1
Timocharis	10:05.9	1
Archimedes	10:09.8	4
Aristillus	10:10.4	1
Manilius	10:11.5	1
Vitruvius	10:11.8	1
Menelaus	10:13.8	1
Fracastorius	10:14.2	1
Pico	10:14.8	1
Plato	10:16.3	9
Bessel	10:17.2	2
Plinius	10:17.6	2
Strabo	10:19.4	1
Cyrillus	10:19.7	1
Goclenius	10:20.5	1
Eudoxus	10:21.8	2
Aristoteles	10:23.2	1
Posidonius	10:24.0	2
Proclus	10:27.3	6
Picard	10:28.9	1
Hercules	10:29.2	1
Atlas	10:30.5	1
Cleomedes	10:31.8	1
Endymion	10:33.4	2

EXIT FROM UMBRA

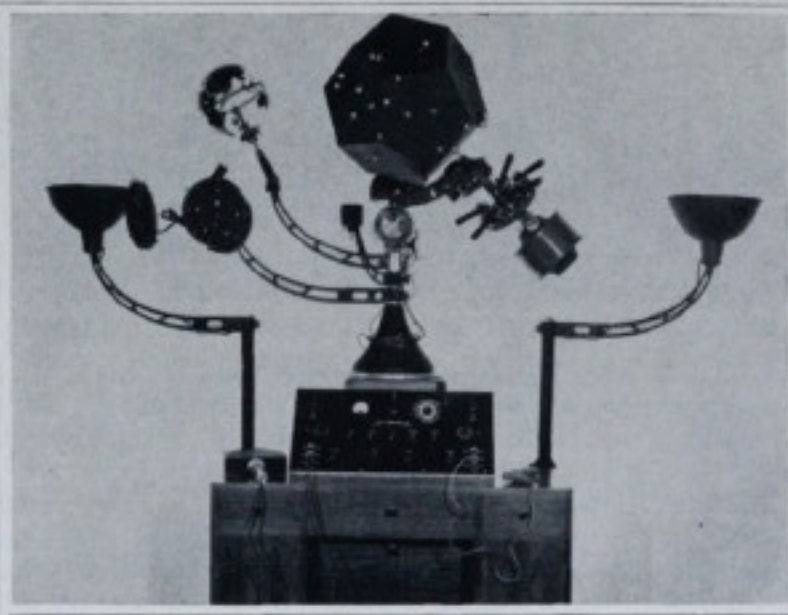
Riccioli	12:07.0	1
Grimaldi	12:08.5	5
Aristarchus	12:10.7	4
Kepler	12:15.2	2
Gassendi	12:19.1	1
Lagrange	12:19.6	1
Schickard	12:19.7	1
Straight Range (west end)	12:21.0	1
Copernicus	12:23.3	4
Plato	12:22.8	3
Archimedes	12:28.6	1
Pitatus	12:30.9	1
Tycho	12:32.7	5
Ptolemaeus	12:34.0	1
Bessel	12:40.5	1
Fracastorius	12:52.2	1
Proclus	12:53.8	1
Langrenus	13:02.6	1

LIST OF ECLIPSE CORRESPONDENTS

SKY AND TELESCOPE thanks not only the correspondents listed below but the many others who participated with them in the observations and photographic work submitted. Photographs were received from those indicated by asterisks.

*E. Bankow, Maywood, Calif.; *H. Braunеis, Denver, Colo.; *M. Caldwell, Glendale, Ohio; *J. Carroll, and B. Sugaya, Redwood City, Calif.; *K. Clawson, La Mesa, Calif.; *R. Cromwell, and T. Morehead, Des Moines, Iowa; *J. and R. Cuffey, Bloomington, Ind.; L. Doggett and others, Marshalltown, Iowa; *R. Dyvig, Deadwood, S. D.; *J. Eastman, Jr., Manhattan Beach, Calif.; J. Elk, III, Ponca City, Okla.; R. Farmer and others, Houston, Tex.; *H. Folse, Jr., New Orleans, La.; *B. Ford, Ft. Worth, Tex.; *W. Fullerton, Kansas City, Mo.; *P. Haustein, La Mesa, Calif.; *G. Heillegger, Willemstad, Netherlands Antilles; *C. Honstein, Jr., El Paso, Tex.; *K. Hoover, Long Beach, Calif.; S. Irwin, San Diego, Calif.; C. and T. Isbell, El Paso, Tex.; C. Johnson, Boulder, Colo.; *T. Johnson, Stockton, Calif.; R. Johnston and others, San Mateo, Calif.; *H. Kendis, Jr., Los Angeles, Calif.; C. Korch, Palo Alto, Calif.

*F. Larsen, Los Angeles, Calif.; *A. Larson and others, Burlington, Iowa; M. Lattey, Vernon, British Columbia; B. Levine, Los Angeles, Calif.; J. Low, Dawson Creek, British Columbia; *V. Nikolashin, San Carlos, Calif.; *E. Ries, Pico Rivera, Calif.; R. Rowlett, III, Richmond, Va.; G. Schoen and others, Amarillo, Tex.; G. Solberg, Las Cruces, N. M.; *J. Smith, Eagle Pass, Tex.; *T. Smith, La Mesa, Calif.; C. Snell and others, Elizabethton, Tenn.; C. Stern, Van Nuys, Calif.; *D. Strittmatter, Tucson, Ariz.; *F. Sulloway, II, Providence, R. I.; J. Sutcliffe, San Jose, Costa Rica; *R. Swanberg, Helena, Mont.; *J. Thomas, Puunene, Hawaii; *T. Tregaskis, Yallourn, Victoria, Australia; *B. Waaland, Burlingame, Calif.; *B. Ward, Hobbsville, N. C.; *J. Williams and others, Woodland Hills, Calif.; *J. Wiseman, Jr., Portland, Ore.



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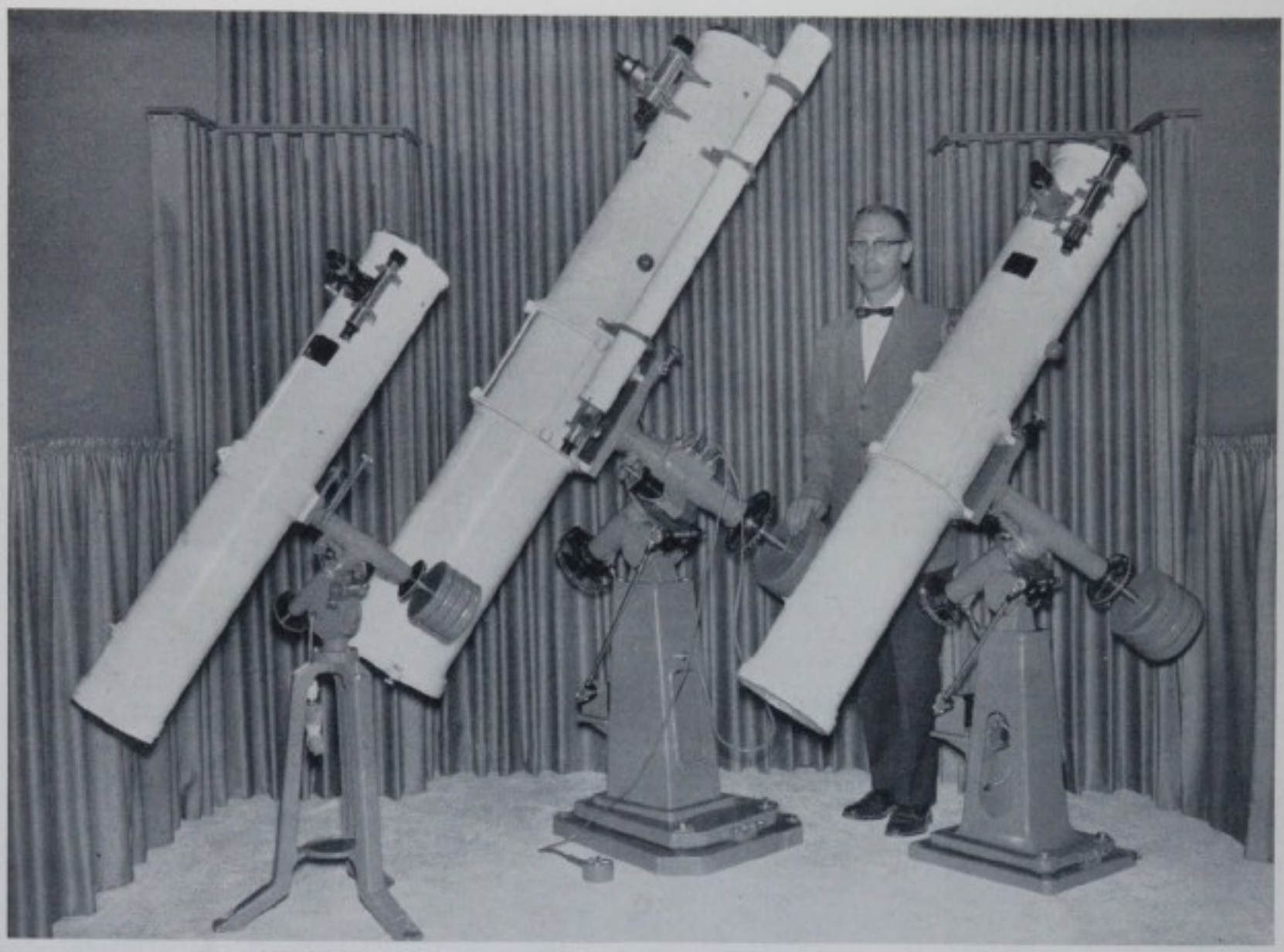

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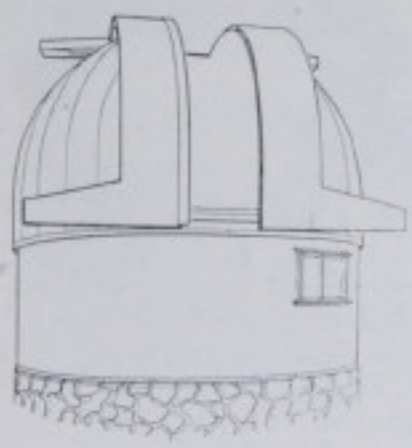

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Manual slow-motion controls on 6- and 8-inch reflectors; electric slow-motion controls on the 10-inch. These controls operate in right ascension and declination independently of the sidereal-rate electric clock drive.

Positive clamps on both right ascension and declination axes.

Steel tube with machined cast-iron end rings, precision-machined rotation saddle.

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All castings and tubes are finished in high-quality enamel. Castings steel grey, tubes off-white.

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Total net weight: 6-inch, 90 lbs.; 8-inch, 284 lbs.; 10-inch, 490 lbs.

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10-inch reflector, $1,495.00

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The aurora of October 6-7, 1960, is shown above Burton Tower on the University of Michigan campus in this 30-second exposure at f/1.9 by Gerald Newsom. The picture was taken at 8:08 p.m. Eastern standard time on Ansco Super Hypan film. An hour later the aurora was much fainter.

A Spectacular Aurora in October

PERHAPS the finest auroral display of the year occurred the night of October 6-7, with activity on a scale unexpected even by professional aurora forecasters working with C. W. Gartlein in Ithaca, New York, at the IGY World Data Center. Although the majority of reports have come from the northeastern and midwestern United States, magnificent arcs and rays were also observed in more distant areas, such as Colorado.

During the day of October 6th, radio amateur Wayne L. Norton in Ridgeville, Indiana, suspected auroral activity because of poor short-wave radio conditions. While trying to listen to station WWV, Calvin R. Graf at the University of Illinois could hear nothing at 10 megacycles and only a "fluttery" signal at 5 megacycles.

Darrell Conger of Elizabeth, West Virginia, noticed the aurora so soon after sunset that he at first thought it to be high cirrus clouds catching the last rays of the sun. The brightness of the display rivaled that of the moon, which was just past full, and many observers were amazed to see rays extending right up to the lunar disk. Although he stood deep in the shadow of the moonlight, Gerald H. Newsom, Ann Arbor, Michigan, was able to read fine print by the light of the aurora.

Maximum of the display probably occurred around 8:00 p.m. Eastern standard time, and by midnight the sky was quiet, except for an occasional ray. Mr. Norton was still able to detect a trace of aurora just before sunrise on the morning of October 7th.

Brilliant blood red characterized these northern lights for many amateurs, although their reports to Sky and Telescope ranged from describing the display as notably colorless in South Dakota to rainbow-hued over New England. Syl Pauley, Jr., of Greenwood, Rhode Island, wrote in his diary of the event: "9:44 p.m. I see a brilliant, exclusively red, conical patch of light in the west. Other colors are white, fluorescent green, and blue. . . . 9:47 Distinct lavender pulsations to the north. . . . 9:50 Beautiful spectacle of fluorescent green and patches of red." In Oakville, Ontario, Perry Bowker noted a striking contrast between a milky white arc running east-west overhead and an "oscilloscope-green" southern glow, the two formations separated by dark sky. Bright yellow caught the attention of W. A. Feibelman at Pittsburgh, Pennsylvania.

As the aurora developed over Buffalo, New York, a huge coronal burst startled Ernst Both. Directly overhead, the burst showed a nucleus about 20 degrees in diameter, its bright, complicated detail standing out with extreme clarity. Colors ranged from white to bluish green, with some yellow and a faint pink. The burst remained almost stationary for about 20 to 30 seconds, and then fanned out to a hazy, colorless configuration.

In addition to the observations mentioned above, reports were received from: Connecticut, W. E. Iverson; Colorado, J. R. Otoupalik; Illinois, W. Baxter, D. Gordon, J. A. Marshall, D. B. Williams; Massachusetts, C. Stewart, R. N. Watts, Jr.; Michigan, M. F. Taggert; Missouri, R. E. Cox; New Hampshire, T. Maynes; New Jersey, C. H. Hossfield.

New York, R. Barnell and others, H. A. Luft; Ohio, J. DeVeny, L. J. Morrison, J. V. Plottner, H. E. Shepherd, J. Stamm, D. F. Webb, D. R. Weilant; Pennsylvania, L. Dewart, J. Molnar, Jr., T. Sprecher; Rhode Island, F. Sulloway, II, E. Turco, P. Vincent; South Dakota, B. E. Painter; and Wisconsin, D. Gidmark.

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A word from Ward . . .

Thanks for the Memories

As the bells of Christmas toll over the land, most of us start thinking of what the old man with the white beard and red suit is going to leave us on Christmas morning.

Today, I'd like to turn the tables a bit. Instead of asking Santa what I'm going to get, I'd like to offer something to him. And the main thing I'd like to give Santa this Christmastime is — my thanks. So here goes.

Dear Santa:

Thanks for keeping our country on an even keel when so many other parts of the world are torn with discord and strife.

Thanks for giving us leaders who are big enough to rise to any emergency — yet humble enough to know they're the servants of the people.

Thanks for giving us an economic system wherein a company as modest as mine can find its place in the sun.

Thanks for letting us at Adirondack Radio hold our own and grow and prosper simply by trying to put into practice the Golden Rule.

Thanks for giving us the privilege of doing business with so many hundreds of people — who start out being customers and end up as our friends.

Thanks for giving us the best year we ever had since starting in business all the way back in 1936.

That's it, Santa. And a very Merry Christmas to you — and all our friends and customers!

Ward J. Hinkle

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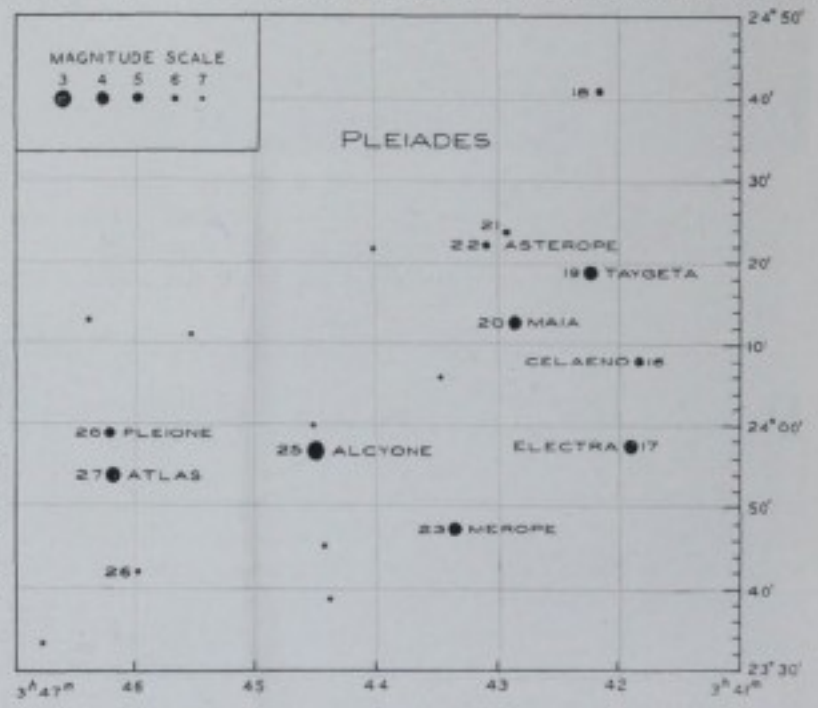
DEEP-SKY WONDERS

THE PLEIADES are the most attractive star cluster in the sky for the unaided eye or small instruments. Although famous since the dawn of history, and enrolled as No. 45 in Messier's list, this star group is unaccountably missing from the *New General Catalogue of Nebulae and Clusters of Stars*. The Pleiades are only about 420 light-years distant, being closer than any other cluster except the Hyades and Coma Berenices.

This sparkling object in Taurus has always been a favorite in frosty winter skies. Under average conditions, six of its stars can be seen with the unaided eye, while with good transparency seven or eight may become visible, making the cluster a good test object. Before the invention of the telescope, Moestlin in 1579 drew a correct map showing 11 Pleiads, and on another occasion saw 14 according to his pupil Kepler. There are 32 members of the group brighter than magnitude 7.6 and easily seen in binoculars.

The numerous fainter stars in the region, R. J. Trumpler believed, bring up the count of actual cluster members to between 300 and 500. Most of these lie within a degree of the center, whose 1950



North is at top in this chart of the Pleiades, which corresponds to the view in binoculars and matches the picture on the facing page. The nebulosity around Merope is hard to detect visually, but is readily recorded by photography. The numbers for the brighter stars are those assigned by Flamsteed. A large-scale photograph of this galactic cluster is reproduced on page 327 of this issue.

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The Pleiades. Harvard Observatory sky patrol photograph.

co-ordinates are $3^h\ 43^m.9$, +23° 58′, about 6′ west of bright Alcyone.

A fascinating but difficult Pleiades feature is the large, very faint nebulosity around 4th-magnitude Merope. Quality of the sky and observing skill seem more important than telescope size in detecting it, as this nebulosity has been missed even in very large instruments, while it has been reported as seen with 3- and 4-inch apertures. Photography shows that it is the brighter part of a complex nebula enveloping the entire cluster.

Whatever his telescope, the amateur will find the Pleiades a showpiece, an excellent object for visitors to observe. Photography of this star group is rewarding even with very simple equipment. A small camera fastened to the telescope tube and hand-guided for half an hour may show something of the nebulosities.

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SUNSPOT NUMBERS

The following American sunspot numbers for September have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

September 1, 92; **2,** 90; **3,** 78; **4,** 69; **5,** 66; **6,** 92; **7,** 120; **8,** 126; **9,** 132; **10,** 148; **11,** 123; **12,** 120; **13,** 161; **14,** 142; **15,** 117; **16,** 96; **17,** 108; **18,** 137; **19,** 149; **20,** 173; **21,** 176; **22,** 157; **23,** 160; **24,** 141; **25,** 131; **26,** 110; **27,** 87; **28,** 71; **29,** 53; **30,** 18. Mean for September, 114.8.

Below are provisional mean relative sunspot numbers for October by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

October 1, 22; **2,** 34; **3,** 22; **4,** 53; **5,** 70; **6,** 82; **7,** 95; **8,** 110; **9,** 128; **10,** 140; **11,** 137; **12,** 123; **13,** 123; **14,** 95; **15,** 95; **16,** 98; **17,** 99; **18,** 98; **19,** 96; **20,** 92; **21,** 82; **22,** 60; **23,** 54; **24,** 49; **25,** 62; **26,** 72; **27,** 67; **28,** 52; **29,** 73; **30,** 68; **31,** 68. Mean for October, 81.3.

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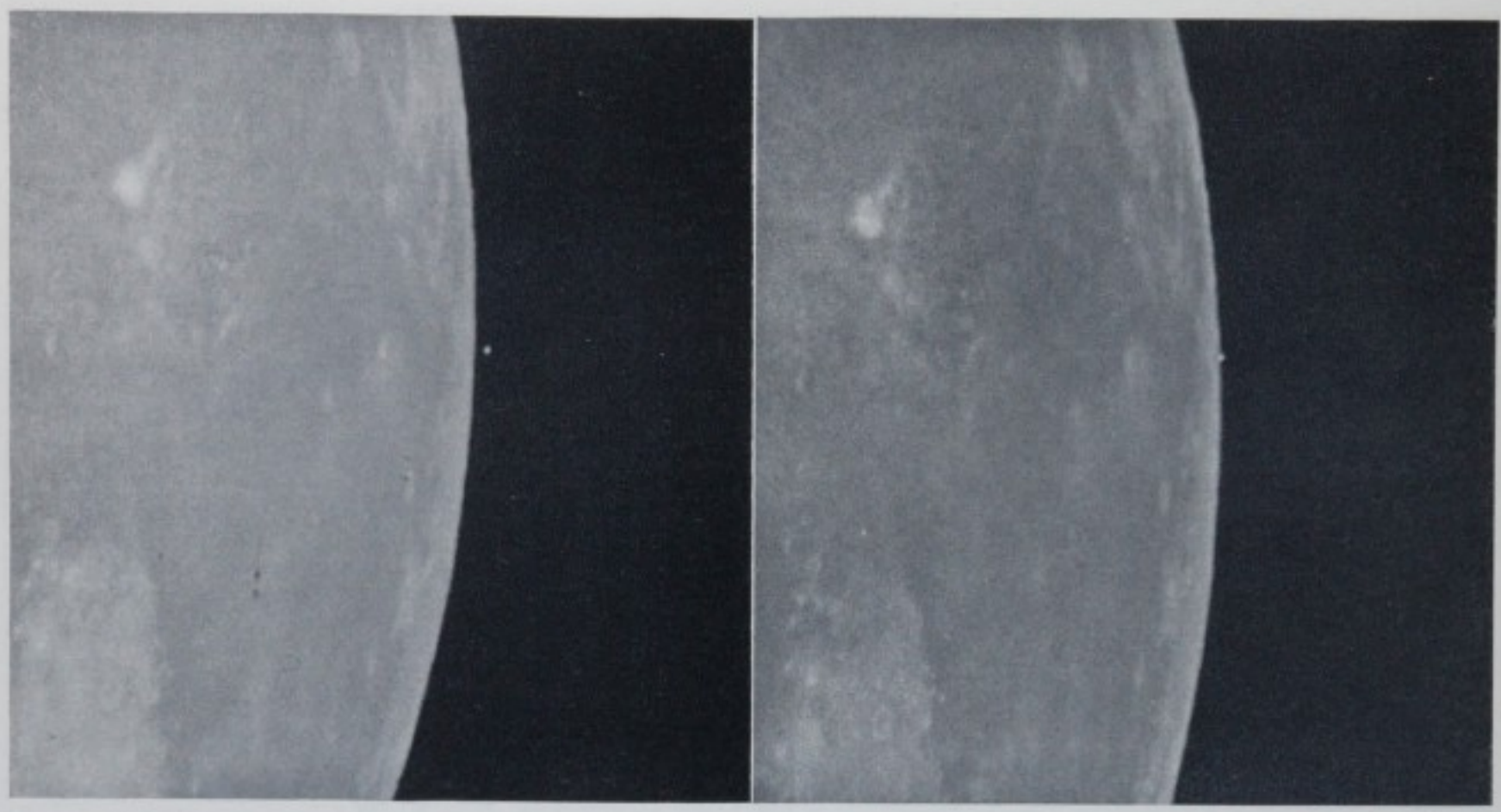

THE OCCULTATION OF ALDEBARAN IN OCTOBER

On the morning of October 9, 1960, Martin S. Burkhead, Madison, Wisconsin, took these pictures of the moon occulting the 1st-magnitude star Aldebaran. He used the Cassegrainian focus of a 12-inch f/15 reflector, each exposure being 1/25 second long on Plus-X film. Development was eight minutes in D-76 diluted one to one. The bright lunar crater in the upper left is Aristarchus. In the left-hand view the moon is very close to Aldebaran, while in the right they are touching each other. Just after the star was covered, Mr. Burkhead noted the Universal time as 8:40. At Ft. Bragg, California, Mart A. Hicks timed both the immersion and emersion. For details of the two occultations of Aldebaran that will be visible from the United States in December, see page 384.

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Sky and TELESCOPE

DECEMBER, 1960

Occultation Supplement

1961 Predictions for the United States and Canada

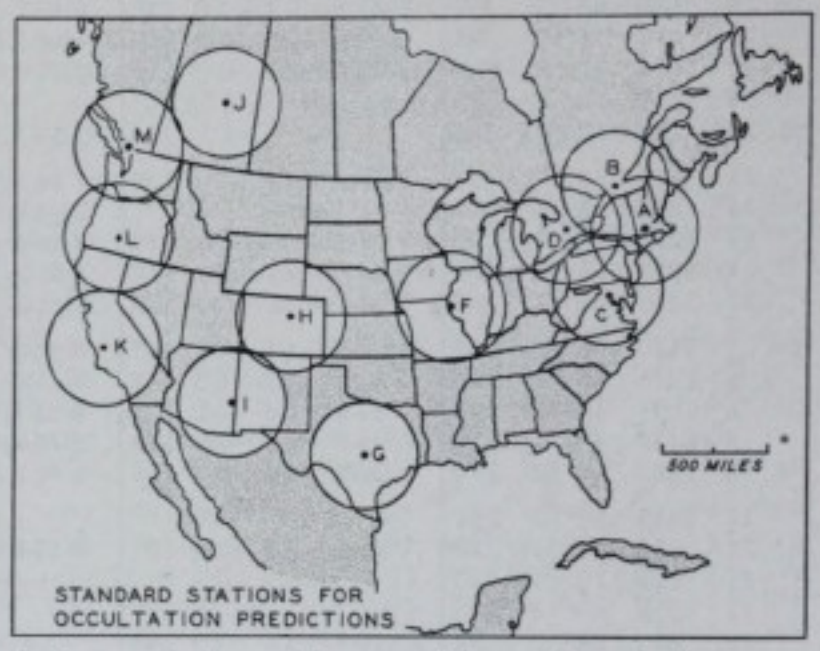
FOR THE SECOND YEAR this supplement is a feature of SKY AND TELESCOPE. Prepared at the Nautical Almanac Office of the Royal Greenwich Observatory under the supervision of Mrs. Flora McBain Sadler, these tables provide occultation predictions for the 12 stations shown on the map. The stations are named and their positions given in the table headings on the following pages.

The first five columns give the date for each occultation, *Zodiacal Catalogue* number of the star, its magnitude, the phenomenon (*1* = disappearance, *2* = reappearance), and the age of the moon in days. Under each station are given the Universal time of the event, **a** and **b** factors in minutes of time, and the position angle **P** (measured from the north point, eastward around the moon's limb to the point of occurrence of the phenomenon).

In certain cases, predictions have been omitted and letters indicating the reason inserted in their places: *G*, grazing occultation; *H*, below or too near the horizon; *N*, no occultation; *S*, sunlight interferes. Certain other cases where satisfactory observations will be impossible are also omitted.

The **a** and **b** factors are the changes in standard-station predicted times per degree of longitude and latitude, respectively. They enable fairly accurate computation of times for each local station (longitude Lo, latitude L) within 200 or 300 miles of a standard station (longitude LoS, latitude LS). The local station time is the standard-station time plus the quantity **a**(Lo − LoS) + **b**(L − LS), with due regard being given to the arithmetic signs. The longitudes and latitudes are expressed in degrees.

On the map the standard stations are at the centers of circles of 250-mile radius, and in these areas the **a** and **b** factors should be quite useful. For positions outside the circles an improvement to the predicted times may sometimes be made by applying corrections to **a** and **b** before using them. For directions on computing these corrections and for examples of the use of the occultation tables, see this supplement's last page.



Precise timings of occultations are useful amateur work, if recorded to 0.1 second and accurate to within 0.5 second. The only equipment needed besides a small telescope is a stop watch and a short-wave receiver for WWV or CHU radio time signals. In addition, the observer must know his geographical latitude and longitude, and height above sea level — information readily found from the large-scale topographical survey maps of the U. S. Geological Survey. Detailed information on procedures is given in SKY AND TELESCOPE for December, 1959, page 84.

The world center to which occultation timings are reported is H. M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.

OCCULTED STARS AND PLANETS

Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.
36	42 B. (Cet)	682	85 Tau	1284	90 B. Cnc	1950	80 Vir	2863	266 B. Sgr
37	44 B. (Cet)	685	275 B. Tau	1336	o^1 Cnc	1978	88 Vir	2902	57 Sgr
55	10 Cet	692	α Tau	1337	o^2 Cnc	1994	598 B. Vir p.	2908	247 G. Sgr
76	14 Cet	699	89 Tau	1371	81 Cnc	2008	614 B. Vir	2959	−18° 5637
95	104 B. Cet	729	+16° 657	1375	π Cnc	2128	13 Lib	2981	π Cap
165	29 Cet	741	318 B. Tau	1386	+13° 2074	2158	−12° 4198	2987	ρ Cap
170	33 Cet	806	111 Tau	1405	+13° 2104	2167	−12° 4214	2990	34 B. Cap
178	35 Cet	814	115 Tau	1413	35 B. Leo	2223	γ Lib	3011	−17° 6039
192	89 Psc	832	119 Tau	1415	7 Leo	2245	190 B. Lib	3022	−17° 6059
202	242 B. Psc	836	120 Tau	1422	+13° 2128	2280	204 B. Lib	3064	94 B. Cap
249	ν Psc	878	130 Tau	1434	ψ Leo	2291	49 Lib	3108	29 Cap
364	ξ^2 Cet	886	+18° 987	1439	18 Leo	2352	107 B. Sco	3118	120 B. Cap
368	389 B. Cet	934	+18° 1112	1441	19 Leo	2396	−17° 4616	3167	136 B. Cap
398	434 B. (Cet)	943	19 B. (Gem)	1442	*R* Leo	2399	24 (Sco)	3173	42 Cap
401	85 (Cet)	947	71 Ori	1448	21 Leo	2441	90 B. Oph	3177	44 Cap
405	μ Cet	951	+18° 1141	1466	ν Leo	2448	29 Oph	3206	μ Cap
453	+11° 434	985	+18° 1214	1487	α Leo	2497	166 B. Oph	3222	−13° 6074
462	+11° 445	1040	74 B. Gem	1525	44 Leo	2508	192 B. Oph	3231	−13° 6085
491	8 B. Tau	1072	110 B. Gem	1550	49 Leo	2571	6 G. Sgr	3295	54 Aqr
498	+12° 477	1114	143 B. Gem	1600	59 Leo	2629	39 G. Sgr	3307	σ Aqr
508	5 Tau	1116	+17° 1561	1609	χ Leo	2639	16 Sgr	3310	58 Aqr
516	+13° 568	1124	+18° 1610	1644	σ Leo	2642	17 Sgr	3324	64 Aqr
526	+13° 579	1141	162 B. Gem	1732	+ 2° 2499	2710	87 G. Sgr	3332	65 Aqr
608	179 B. Tau	1158	74 Gem	1749	10 Vir	2715	89 G. Sgr	3355	243 B. Aqr
626	48 Tau	1198	2 B. Cnc	1821	γ Vir	2729	133 B. Sgr	3375	260 B. Aqr
635	γ Tau	1210	5 Cnc	1825	− 0° 2603	2734	29 Sgr	3379	81 Aqr
659	70 Tau	1235	+16° 1657	1864	− 2° 3605	2773	171 B. Sgr	3421	χ Aqr
661	71 Tau	1236	ζ Cnc	1866	44 Vir	2774	173 B. Sgr	3422	− 7° 5975
667	75 Tau	1238	+16° 1662	1869	46 Vir	2791	190 B. Sgr	3463	− 7° 6036
669	θ^1 Tau	1241	+18° 1882	1875	48 Vir	2798	195 B. Sgr	3514	24 Psc
671	θ^2 Tau	1247	+16° 1687	1924	66 Vir	2814	43 Sgr	3526	27 Psc
672	+15° 633	1258	+16° 1704	1933	519 B. Vir	2825	226 B. Sgr	3537	74 B. Psc
677	264 B. Tau	1262	25 Cnc	1941	74 Vir	2854	−19° 5492	4001	MERCURY
680	269 B. Tau								

Date		Z.C. No.	Mag.	Ph.	Age of Moon	A MASSACHUSETTS W. 72°.500, N. 42°.500				B MONTREAL, Q.P. W. 73°.575, N. 45°.505				C WASHINGTON, D.C. W. 77°.065, N. 38°.920				D TORONTO, ONT. W. 79°.400, N. 43°.663			
						U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Jan.	4	1284	6·3	2	16·7	1 44·8	−0·2	+3·1	229	1 52·9	−0·3	+2·5	241	1 32·4	+0·4	+4·0	216	1 47·1	−0·1	+2·4	239
	6	1525	5·9	2	19·0		S			11 24·4	−1·2	−1·3	269	11 25·0	−2·0	−0·3	248	11 17·8	−1·8	−0·8	258
	10	1941	4·8	2	22·9	8 39·4	−1·5	+0·7	279	8 39·8	−1·3	+0·5	287	8 28·3	−1·7	+1·5	262	8 30·9	−1·3	+1·1	275
	20	3514	6·1	1	4·1	23 20·0	−1·0	+0·3	51	23 20·2	−0·8	+0·5	41	23 13·9	−1·3	+0·3	57	23 13·7	−1·0	+0·8	40
	24	368	6·3	1	7·1	0 12·0	−1·7	+0·8	57	0 13·2	−1·5	+1·2	47	0 00·8	−2·0	+0·8	64	0 02·1	−1·5	+1·5	47
	26	626	6·4	1	9·2	4 03·5	−0·9	−3·8	135	3 52·7	−1·1	−2·7	121		N			3 51·4	−1·4	−3·6	131
	26	635	3·9	1	9·3	6 09·1	−0·2	−1·6	100	6 04·1	−0·3	−1·5	92	6 14·8	−0·2	−2·1	115	6 05·0	−0·4	−1·7	101
	29	1040	6·2	1	12·3	3 46·7	−2·0	−1·5	115	3 40·9	−1·9	−1·0	105	3 44·1	−2·2	−2·4	130	3 31·0	−2·1	−1·1	112
	30	1158	5·2	1	13·3		N				N			5 03·5	·	·	49		G		
Feb.	18	192	5·3	1	3·6		N			23 37·7	−1·4	−3·4	124		N			23 35·2	·	·	130
	21	453	7·3	1	5·7	2 16·0	−0·5	−3·3	128	2 06·8	−0·7	−2·5	115		N			2 07·4	−0·9	−3·1	124
	24	878	5·5	1	8·9		H			6 34·4	+0·3	−1·9	117		H			6 39·8	+0·3	−2·3	127
	27	1235	7·4	1	11·8	3 24·5	·	·	160	3 12·0	−1·4	−3·1	147		N			3 11·0	·	·	162
	27	1238	6·1	1	11·8	4 00·5	−2·5	+0·7	62	4 01·1	−2·5	+1·6	51	3 48·1	−2·4	0·0	·80	3 44·5	−2·4	+0·9	66
	27	1247	6·8	1	11·9	7 54·5	−0·8	−0·3	53	7 53·2	−1·0	+0·1	44	7 53·0	−0·7	−0·7	69	7 48·2	−1·0	−0·5	59
Mar.	5	1869	6·1	2	17·9	5 00·1	−1·3	−0·4	307	4 57·4	−1·1	−0·5	315	4 54·2	−1·5	+0·2	291	4 51·4	−1·1	−0·1	303
	5	1875	6·5	2	17·9	7 11·6	−1·0	−2·3	337	7 03·6	−0·7	−2·4	344	7 12·7	−1·5	−1·7	320	7 01·7	−1·1	−1·7	329
	6	1994	6·5	2	19·0	8 57·9	−1·8	−1·1	292	8 52·7	−1·6	−1·1	296	8 52·3	−2·2	−0·7	280	8 44·3	−1·9	−0·7	287
	8	2223	4·0	1	21·0	5 46·6	−0·2	−0·9	153	5 44·6	−0·3	−0·3	144	5 55·0	·	·	182		H		
	8	2223	4·0	2	21·0	6 38·7	−1·8	+2·0	248	6 42·3	−1·5	+1·6	256	6 17·8	·	·	220	6 29·5	−1·6	+2·5	241
	12	2863	6·1	2	25·1		S				S			10 18·2	−1·5	+2·1	231	10 24·0	−1·3	+1·7	241
	20	398	6·7	1	3·2	0 43·6	−0·6	+1·5	23	0 50·8	·	·	1	0 37·3	−0·7	+0·5	41	0 40·7	−0·8	+1·9	19
	21	516	7·3	1	4·2		N				N			0 01·3	−1·4	+2·5	23		N		
	21	526	6·9	1	4·3		H				H				H			2 50·8	−0·3	+0·1	45
	21	659	6·4	1	5·2	23 30·9	−1·7	−0·9	89		S				S				S		
	22	669	4·0	1	5·2	1 18·7	−0·8	−1·8	104	1 12·7	−0·8	−1·5	95	1 22·7	−0·8	−2·5	120	1 10·3	−1·0	−1·8	104
	22	671	3·6	1	5·2	1 28·4	−0·5	−3·0	129	1 19·6	−0·7	−2·5	118	1 41·6	·	·	154	1 20·5	−0·8	−3·1	128
	22	672	6·6	1	5·2	1 35·8	−0·9	−0·4	61	1 34·1	−1·0	0·0	52	1 33·4	−1·0	−0·7	76	1 28·4	−1·1	−0·3	61
	22	677	4·8	1	5·3	2 25·3	−0·6	−0·4	60	2 23·7	−0·7	−0·2	51	2 24·7	−0·6	−0·8	75	2 20·1	−0·8	−0·4	61
	22	680	6·7	1	5·3	2 29·2	−0·5	−0·8	72	2 26·5	−0·5	−0·6	63	2 30·4	−0·5	−1·1	86	2 24·3	−0·7	−0·9	73
	22	682	6·0	1	5·3		G			3 08·2	+0·5	−3·7	145		N				N		
	22	685	6·5	1	5·3		H				H				H			3 58·6	−0·4	+0·3	39
	23	806	5·1	1	6·3	3 41·3	+0·6	−3·8	151	3 31·8	+0·2	−3·1	139		N			3 40·4	·	·	156
	24	934	6·4	1	7·2	0 48·4	−1·4	−3·4	138	0 38·0	−1·5	−2·5	126	1 01·4	·	·	165	0 33·8	−1·7	−3·2	136
	24	951	6·8	1	7·3	3 27·4	−0·8	−0·9	76	3 23·9	−0·9	−0·8	68	3 27·8	−0·8	−1·3	90	3 20·2	−1·0	−1·0	79
	26	1198	6·2	1	9·4	5 11·9	+0·4	−3·7	162	5 01·9	+0·1	−3·2	153		N			5 10·7	·	·	170
	26	1210	5·9	1	9·4	6 29·8	+0·2	−2·0	128	6 24·0	+0·1	−2·0	123	6 39·0	+0·3	−2·4	141	6 28·6	+0·1	−2·2	131
	28	1405	7·0	1	11·3	1 25·4	−2·3	+0·7	82	1 25·9	−2·3	+1·3	72	1 13·6	−2·2	+0·1	98	1 11·1	−2·1	+1·0	84
	28	1413	6·7	1	11·4		N				N			4 13·2	−2·9	+0·8	60	4 14·2	·	·	41
	29	1525	5·9	1	12·4	6 20·8	−0·3	−3·0	157	6 11·8	−0·4	−2·7	151	6 33·1	·	·	176	6 15·2	−0·2	−3·4	163
Apr.	8	2814	5·0	2	22·6		N				N			8 52·4	·	·	337		N		
	10	3108	5·5	2	24·6	9 04·6	−1·0	+2·1	225	9 09·7	−1·0	+2·0	231		H				H		
	18	608	6·0	1	2·8	1 11·0	+0·1	−1·6	102	1 06·5	0·0	−1·4	94	1 17·9	+0·1	−2·0	118	1 09·0	−0·1	−1·7	104
	20	886	7·0	1	4·7		N				N			0 27·9	·	·	31		N		
	21	1040	6·2	1	5·8	2 46·0	−0·1	−2·0	117	2 39·8	−0·2	−1·9	111	2 53·5	0·0	−2·5	132	2 42·2	−0·3	−2·2	121
	22	1158	5·2	1	6·9		N				N			3 42·3	−1·1	+0·3	49	3 43·2	·	·	30
	24	1386	6·6	1	9·0	5 50·8	+0·1	−1·9	122	5 45·3	0·0	−1·9	117	5 58·4	+0·1	−2·1	132	5 48·9	0·0	−2·0	125
May	2	2291	5·5	2	17·0	7 10·7	−2·2	+0·8	232	7 10·1	−2·0	+0·4	238		G			6 55·5	·	·	228
	3	2448	6·4	2	18·1		S				S			8 57·8	·	·	218	8 57·4	−1·7	+0·4	232
	7	3064	6·0	2	22·1	7 02·7	−0·8	+0·8	288	7 04·4	−0·7	+0·8	293	6 55·8	−0·7	+1·0	278		H		
	15	692	1·1	1	1·2	22 38·2	−0·4	−1·5	95	22 33·5	−0·5	−1·3	87	22 42·1	−0·5	−1·9	110	22 32·6	−0·7	−1·5	96
	15	692	1·1	2	1·2	23 39·2	−0·2	−1·0	257	23 35·8	−0·1	−1·2	265	23 40·6	−0·4	−0·4	243	23 36·4	−0·4	−0·9	255
	18	985	6·9	1	3·3	1 20·2	−0·9	+0·9	34		G			1 16·1	−0·6	−0·2	55	1 14·8	−1·0	+0·5	40
	20	1238	6·1	1	5·4		H				H				H			3 46·5	+0·2	−1·8	117
	22	1439	5·9	1	7·4	2 31·4	+0·2	−3·6	167	2 21·3	−0·1	−3·2	159		N			2 28·7	·	·	176
	22	1448	6·7	1	7·4		H			4 38·1	−0·4	−0·4	50	4 41·3	−0·3	−0·8	71	4 36·8	−0·5	−0·7	61
	23	1550	5·8	1	8·4	3 06·4	−0·8	−1·8	107	3 00·2	−0·9	−1·7	103	3 09·1	−0·9	−2·0	119	2 57·8	−1·0	−1·8	112
	26	1866	5·9	1	11·5		N			5 38·3	·	·	184		N				N		
	26	1869	6·1	1	11·5	5 47·8	·	·	46		G			5 42·7	−1·3	−0·3	61	5 39·1	·	·	48
June	4	3173	5·3	2	20·6	7 18·7	−1·4	+1·3	252	7 21·0	−1·3	+1·2	257	7 07·1	−1·4	+1·5	246	7 11·0	−1·2	+1·4	254
	18	1405	7·0	1	4·8		H			2 21·1	+0·6	−3·2	168		N				N		
	23	1924	5·8	1	9·8	1 30·1	−2·4	0·0	72	1 27·7	−2·4	+0·2	66	1 19·8	−2·4	−0·4	88		S		
	23	1933	7·0	1	9·9	4 41·5	−0·6	−2·3	142	4 34·0	−0·6	−2·2	137	4 47·7	−0·7	−2·7	151	4 34·2	−0·7	−2·3	141
July	9	692	1·1	1	26·2	9 42·7	+0·3	+3·2	22	9 53·8	·	·	9	9 33·1	+0·3	+2·8	27	9 50·7	·	·	5
	9	692	1·1	2	26·2	10 25·0	−1·5	+0·1	304	10 22·3	·	·	318	10 18·1	−1·2	+0·3	299	10 13·4	·	·	323
	21	2008	6·6	1	8·3		H				H			3 53·6	−0·6	−1·8	116	3 43·7	−0·7	−1·7	107
	23	2245	6·4	1	10·3	3 55·1	−1·0	−0·3	56	3 53·3	−0·9	−0·1	48	3 51·2	−1·3	−0·4	64	3 47·1	−1·3	−0·1	52
	24	2396	6·6	1	11·4	4 38·2	−1·3	−2·0	129	4 31·1	−1·2	−1·8	122	4 39·2	−1·5	−2·2	135	4 26·6	−1·4	−1·7	124
	24	2399	5·0	1	11·4	4 45·3	−0·9	−0·3	55	4 43·7	−0·8	−0·1	47	4 41·7	−1·2	−0·3	61	4 38·5	−1·1	+0·1	48

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						U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
July	29	3206	5·2	2	16·4	5 20·9	−1·7	+0·7	256	5 21·1	−1·6	+0·6	261	5 10·1	−1·7	+1·0	252	5 10·4	−1·6	+0·8	262
Aug.	4	491	6·2	2	22·5	6 25·9	−0·7	+0·8	294	6 27·1	−0·8	+0·5	303	6 20·5	−0·5	+0·8	290	6 22·3	−0·6	+0·4	305
	4	498	6·2	2	22·6	8 12·4	−1·0	+1·7	252	8 16·1	−1·0	+1·5	259	8 02·0	−0·8	+1·7	249	8 07·9	−0·8	+1·5	261
	4	508	4·3	1	22·6	9 08·0	−1·7	+0·8	95		S			8 57·4	−1·7	+0·8	99	8 59·3	−1·2	+1·4	84
	5	626	6·4	2	23·5	6 25·0	−0·3	+0·7	297	6 26·4	−0·4	+0·5	306		H				H		
	5	635	3·9	1	23·6	7 34·7	−0·1	+2·3	46	7 41·8	0·0	+2·5	38	7 26·5	0·0	+2·1	49	7 37·4	+0·1	+2·4	36
	5	635	3·9	2	23·6	8 35·2	−1·1	+1·1	278	8 36·9	−1·2	+0·9	287	8 26·5	−0·9	+1·1	275	8 29·0	−1·0	+0·9	289
	5	692	1·1	1	23·9	17 37·4	−0·7	0·0	49	17 37·1	−0·8	+0·4	39	17 35·2	−0·7	−0·5	65	17 32·2	−0·8	0·0	51
	5	692	1·1	2	23·9	18 26·6	+0·3	−2·3	302	18 19·4	+0·3	−2·8	312	18 34·3	0·0	−1·7	287	18 25·0	0·0	−2·3	300
	22	2629	6·3	1	10·6	1 24·9	−1·9	+0·2	70	1 23·8	−1·8	+0·3	65	1 14·7	−2·1	+0·3	77	1 12·2	−1·9	+0·6	69
	23	2825	6·4	1	11·8		H				N			6 09·1	+0·1	+1·4	23		N		
	31	462	5·9	2	19·9	8 29·3	−2·0	+0·5	267	8 28·3	−2·0	+0·2	277	8 17·8	−2·0	+0·9	263	8 16·1	−2·0	+0·4	280
Sept.	2	741	5·7	2	21·9	8 47·1	−1·7	+0·8	274	8 47·3	−1·7	+0·5	284	8 36·2	−1·5	+1·1	269	8 36·8	−1·5	+0·7	285
	15	2158	7·3	1	4·9		H				H			0 37·1	−0·9	−1·4	94	0 28·7	−1·0	−1·3	85
	15	2280	6·8	1	5·9	23 56·0	−1·4	−1·7	120	23 49·5	−1·4	−1·6	115	23 55·6	−1·6	−1·9	126		S		
	18	2571	6·9	1	7·9	1 57·4	−0·7	+0·3	41	1 58·1	−0·5	+0·8	30	1 52·3	−1·1	+0·3	47	1 53·0	−0·8	+1·1	30
	18	2729	6·9	1	8·9	24 10·6	−2·1	−1·8	141	24 04·2	−1·9	−1·1	133	24 08·2	·	·	151	23 55·3	−1·8	−1·1	137
	20	2902	6·0	1	10·0	2 04·0	−1·7	−0·5	86	2 01·0	−1·6	−0·3	80	1 57·1	−2·0	−0·4	89	1 51·8	−1·7	−0·1	79
	22	3206	5·2	1	12·0	1 47·0	−1·7	+0·8	71	1 47·8	−1·5	+0·9	65	1 36·0	−1·8	+0·9	74	1 37·1	−1·5	+1·1	64
	27	405	4·4	1	17·1	5 14·4	−1·3	+1·6	62	5 18·2	−1·1	+1·8	54	5 02·7	−1·2	+1·6	65	5 08·8	−0·9	+2·0	51
	27	405	4·4	2	17·1	6 30·8	−1·7	+1·0	249	6 31·7	−1·7	+0·8	258	6 18·8	−1·6	+1·3	245	6 20·3	−1·7	+0·9	260
	29	669	4·0	2	19·1	3 19·0	−0·2	+1·3	270	3 22·7	−0·2	+1·3	276	3 13·9	0·0	+1·2	266	3 19·4	−0·1	+1·2	278
	29	671	3·6	2	19·1	3 19·5	0·0	+1·7	249	3 24·4	−0·1	+1·6	255	3 13·7	+0·1	+1·6	246	3 21·3	+0·1	+1·5	256
	29	677	4·8	2	19·1	4 14·8	−0·8	+0·7	292	4 15·8	−0·9	+0·5	302	4 08·6	−0·6	+0·8	288	4 10·0	−0·8	+0·4	304
	29	682	6·0	2	19·1		G			4 36·1	+0·3	+3·5	195		N			4 31·9	+0·4	+3·2	198
	29	685	6·5	2	19·1	5 58·6	−1·3	+1·2	269	6 00·3	−1·3	+1·0	278	5 48·4	−1·1	+1·3	265	5 51·2	−1·2	+1·0	280
	29	692	1·1	1	19·2	6 10·1	−0·9	+2·2	53	6 16·3	−0·7	+2·5	43	5 58·4	−0·8	+2·1	56	6 07·7	−0·5	+2·6	41
	29	692	1·1	2	19·2	7 23·3	−1·9	+0·6	273	7 22·5	−1·9	+0·2	283	7 12·1	−1·8	+0·9	268	7 11·1	−1·8	+0·4	284
	30	814	5·3	2	20·1	5 44·8	−0·8	+1·5	261	5 48·4	−0·8	+1·4	269	5 36·1	−0·5	+1·6	257	5 41·6	−0·6	+1·4	270
	30	836	5·5	2	20·3		G				N			9 15·7	·	·	323		N		
Oct.	4	1336	5·2	2	24·3	8 41·5	−0·6	+2·4	244	8 47·5	−0·7	+2·0	255	8 29·8	−0·2	+2·9	233	8 40·5	−0·4	+2·0	253
	4	1337	5·6	2	24·3	8 48·7	−1·1	−0·2	309	8 46·4	−1·1	−0·7	322	8 43·9	−0·9	+0·2	299	8 41·7	−0·9	−0·4	318
	7	1644	4·1	2	27·4	10 15·7	−0·5	−0·6	323	10 12·7	−0·5	−1·2	336	10 14·6	−0·4	−0·1	309	10 12·0	−0·4	−0·8	329
	17	2854	7·3	1	7·2	0 57·2	·	·	13		N			0 48·1	·	·	21		N		
	17	2987	5·0	1	8·2	23 37·9	−1·2	+2·1	22	23 44·0	·	·	9	23 24·2	−1·6	+2·1	28	23 33·3	·	·	9
	17	2990	6·7	1	8·2	23 31·0	−1·5	+1·2	42	23 33·1	−1·4	+1·3	34	23 18·8	−1·8	+1·4	46	23 22·0	−1·5	+1·6	35
	19	3295	7·0	1	10·2	24 10·0	−1·2	+2·0	29	24 14·9	−1·0	+2·1	21	23 56·8	−1·3	+2·1	33	24 04·9	−1·0	+2·5	19
	20	3307	4·9	1	10·3		G				N			2 55·7	·	·	353		N		
	20	3310	6·4	1	10·3	2 55·9	−1·5	−0·2	73	2 54·2	−1·3	0·0	65	2 48·7	−1·8	0·0	76	2 45·7	−1·5	+0·3	62
	21	3463	6·4	1	11·4	4 27·5	−2·0	−1·8	110	4 21·1	−1·7	−1·1	97	4 24·3	−2·6	−2·2	116	4 12·7	−1·9	−0·8	95
	26	608	6·0	2	16·4	4 20·5	−1·0	+2·1	230	4 25·4	−1·1	+1·8	239	4 08·3	−0·8	+2·3	227	4 16·1	−0·9	+1·8	241
	27	741	5·7	2	17·3	1 33·8	+0·1	+1·5	255	1 38·3	0·0	+1·4	261		H				H		
Nov.	3	1609	4·7	2	24·6	9 45·6	−1·2	+0·7	285	9 46·1	−1·1	+0·4	295	9 36·8	−1·1	+1·3	272	9 39·2	−0·9	+0·8	287
	11	2639	6·0	1	3·5	22 45·7	−1·2	−1·3	97	22 40·8	−1·2	−1·1	90	22 44·1	−1·5	−1·3	101	22 35·5	−1·4	−1·0	89
	11	2642	7·1	1	3·5		H				H				H			23 28·3	−1·5	−2·4	132
	14	2959	7·2	1	5·6	0 47·6	−0·6	0·0	47	0 47·5	−0·4	+0·3	37	0 44·1	−0·8	+0·1	51	0 44·0	−0·6	+0·6	34
	21	405	4·4	1	12·7	0 36·2	−1·0	+1·7	66	0 40·4	−0·9	+1·8	60	0 25·9	−0·9	+1·6	69	0 32·5	−0·7	+1·9	57
	23	692	1·1	1	14·7	0 59·2	−0·7	+1·2	93	1 02·5	−0·6	+1·4	86	0 52·0	−0·6	+1·1	96	0 56·9	−0·4	+1·5	84
	23	692	1·1	2	14·7	2 01·7	−0·7	+2·2	232	2 07·1	−0·7	+2·0	240	1 51·1	−0·5	+2·3	228	1 59·6	−0·6	+1·9	242
	23	814	5·3	2	15·6		H			23 59·3	+0·5	+2·4	212		H				H		
	24	832	4·7	2	15·7	2 33·7	−1·3	+0·5	292	2 33·4	−1·4	+0·2	303	2 26·1	−1·1	+0·7	287	2 25·4	−1·2	+0·1	305
	24	836	5·5	2	15·7	3 20·5	−1·2	+1·3	264	3 22·7	−1·3	+1·1	273	3 10·1	−1·1	+1·5	259	3 13·7	−1·1	+1·1	274
	27	1236	5·1	2	18·7	2 33·1	0·0	+1·2	274	2 36·5	−0·1	+1·1	283		H				H		
	27	1241	6·4	2	18·8	3 30·4	−0·4	+1·0	284	3 32·6	−0·5	+0·8	293	3 25·2	−0·2	+1·0	277	3 28·8	−0·3	+0·8	293
	27	1262	6·2	2	19·0		S				S				N			10 46·9	−2·7	+1·7	232
	28	1371	6·4	2	19·9		G			8 30·3	·	·	230		N			8 06·4	·	·	211
	28	1375	5·6	2	20·0		S			10 50·2	−1·8	−0·9	279	10 44·8	−2·7	+0·4	254	10 39·5	−2·2	−0·2	267
	29	1466	5·2	2	20·9	7 03·4	−1·3	+1·8	260	7 06·8	−1·2	+1·4	270	6 50·1	−1·0	+2·6	245	6 57·5	−1·0	+1·6	264
Dec.	10	2908	6·9	1	2·9	22 10·4	−0·4	+0·9	28	22 13·9	·	·	15		S				S		
	13	3355	6·8	1	6·0	23 36·8	·	·	139	23 24·2	−2·5	−2·0	119		N			23 12·3	−2·5	−1·3	114
	16	95	7·1	1	8·1	2 38·6	−0·8	+0·9	35	2 41·4	−0·6	+1·5	22	2 31·1	−1·1	+0·9	42	2 34·7	−0·7	+1·6	22
	19	491	6·2	1	11·1		N			2 16·1	·	·	126		N			2 03·4	−2·8	−1·7	124
	20	667	5·3	1	12·3	8 10·0	−0·4	−1·6	97	8 05·2	−0·5	−1·3	89	8 14·4	−0·5	−2·0	113	8 04·5	−0·6	−1·6	98
	20	677	4·8	1	12·4		N			9 20·7	+0·7	−4·3	151		N				N		
	26	1415	6·2	2	18·2		G				N			3 00·6	−0·9	−2·0	338		N		
	28	1644	4·1	1	20·5		G			11 15·5	·	·	180		N				N		
	28	1644	4·1	2	20·5		S			11 53·4	·	·	235		N				N		
	31	1950	5·8	2	23·4	9 34·7	−1·3	−0·2	302	9 32·9	−1·1	−0·3	310	9 27·9	−1·5	+0·4	286	9 26·5	−1·1	+0·2	298

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					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Jan.	10	1941	4·8	2	22·9	8 10·8	−1·1	+2·4	249		N				H				N		
	14	2508	6·3	2	27·1		N			12 01·7	·	·	358		N				H		
	20	3379	6·4	1	3·1		G			1 15·4	−0·4	+1·3	29		N			1 23·5	·	·	349
	24	398	6·7	1	7·4		H				H				H			7 15·1	−0·3	−0·5	70
	25	516	7·3	1	8·4		N				H				H			8 08·0	−0·5	+0·5	43
	26	626	6·4	1	9·2		G				N			3 12·5	·	·	145		N		
	26	635	3·9	1	9·3	6 06·9	−0·7	−2·6	121		N			5 55·0	−1·3	−3·4	130		N		
	26	659	6·4	1	9·4		H				H			9 01·4	−0·1	−1·0	83	9 08·3	0·0	−1·5	103
	29	1040	6·2	1	12·3	3 09·8	−2·3	−1·4	125		N			2 39·8	−1·9	−0·2	118	2 36·5	−2·4	−2·0	139
	30	1158	5·2	1	13·3	4 28·3	−2·4	+2·6	54	3 57·9	−2·4	+0·7	89	3 58·4	−1·7	+2·9	54	3 38·9	−1·7	+1·7	74
Feb.	3	1600	5·1	2	17·5	11 39·4	−2·0	+0·2	235		N				N				N		
	10	2441	6·5	2	24·6		S				S			12 42·8	−1·7	+0·6	274	12 30·1	−2·0	+1·4	255
	12	2773	6·1	2	26·7		S				S			12 42·4	−0·9	+1·2	268		H		
	12	2774	6·3	2	26·7		S				S			12 40·0	−0·6	+0·4	298		H		
	18	55	6·4	1	2·7		N			1 02·6	−0·6	+1·1	35		N				S		
	19	202	7·0	1	3·7		N			2 35·6	−0·5	+2·3	18		N				G		
	21	453	7·3	1	5·7		G				N			1 41·7	·	·	139		N		
	23	729	7·2	1	7·8		N			3 15·9	·	·	22		N				N		
	23	741	5·7	1	7·9		N			7 04·6	−0·4	0·0	59	7 04·0	−1·0	+1·3	31	6 58·2	−0·8	−0·1	60
	24	878	5·5	1	8·9	6 55·0	+0·7	−4·2	156		N				N				N		
	27	1238	6·1	1	11·8	3 14·5	−2·3	+0·4	87	3 00·4	−2·5	−1·2	121	2 44·2	−1·9	+0·9	90	2 33·7	−2·0	0·0	109
	27	1247	6·8	1	11·9	7 39·2	−1·1	−1·1	83	7 44·6	−1·0	−1·9	115	7 21·1	−1·5	−1·4	100	7 24·8	−1·5	−2·1	120
	27	1258	6·7	1	12·0		N				G				N			9 45·5	·	·	39
Mar.	5	1869	6·1	2	17·9	4 37·1	−1·0	+0·9	281	4 13·5	−1·2	+3·4	236	4 25·5	−0·6	+1·3	270		H		
	5	1875	6·5	2	17·9	6 49·9	−1·6	−0·6	304	6 35·3	−2·3	+1·0	266	6 28·9	−1·4	+0·5	286	6 17·5	−1·6	+1·5	262
	6	1994	6·5	2	19·0	8 19·8	−2·4	+0·6	263		N			7 42·4	·	·	234		N		
	8	2245	6·4	2	21·1	11 00·7	−1·7	−1·4	317	10 56·2	−2·3	−0·6	289	10 37·8	−1·6	−0·5	302	10 31·5	−2·0	+0·1	283
	9	2399	5·0	2	22·2		S				S			12 14·4	−2·1	+0·1	271	12 02·5	−2·6	+0·8	255
	21	526	6·9	1	4·3	2 46·6	−0·6	−0·5	65	2 50·5	−0·6	−1·4	99	2 36·1	−1·0	−0·6	72	2 36·7	−1·2	−1·2	92
	22	667	5·3	1	5·2	1 22·8	·	·	15		S				S				S		
	22	669	4·0	1	5·2	1 03·5	−1·6	−2·7	121		N				S				S		
	22	672	6·6	1	5·2	1 14·7	−1·6	−0·6	78	1 12·5	−2·0	−1·9	111		S				S		
	22	677	4·8	1	5·3	2 11·6	−1·1	−0·8	79	2 15·6	−1·3	−2·1	114	1 52·2	−1·7	−0·8	85	1 51·2	−2·0	−1·6	105
	22	680	6·7	1	5·3	2 18·5	−1·0	−1·3	91	2 28·9	−1·1	−3·1	129	2 00·8	−1·6	−1·3	97	2 04·1	−1·9	−2·5	119
	22	685	6·5	1	5·3	3 54·1	−0·5	−0·5	63	3 58·3	−0·5	−1·3	97	3 44·7	−0·9	−0·7	73	3 46·5	−1·0	−1·3	95
	22	692	1·1	1	5·4		N			5 10·0	−0·3	0·0	58	5 10·1	−0·8	+1·1	31	5 05·0	−0·6	−0·1	59
	22	692	1·1	2	5·4		N				H			5 43·2	+0·6	−3·2	323	5 58·4	+0·3	−1·8	296
	23	814	5·3	1	6·4		N			4 58·6	−0·8	+0·1	58	4 57·2	−1·6	+2·0	28	4 47·6	−1·2	+0·1	59
	24	943	6·2	1	7·3		N			1 45·7	−2·8	+2·2	49		N				S		
	24	951	6·8	1	7·3	3 11·5	−1·3	−1·5	99	3 22·4	−1·2	−3·3	137	2 50·0	−1·9	−1·7	109	2 55·4	−1·9	−3·2	134
	26	1210	5·9	1	9·4	6 40·2	+0·3	−3·2	155		N				N				N		
	28	1413	6·7	1	11·4	3 35·6	−2·6	+0·4	79	3 21·6	−2·4	−1·2	117	3 01·6	−2·2	+0·4	94	2 53·3	−2·2	−0·6	116
Apr.	8	2814	5·0	2	22·6	8 43·2	−0·4	−0·6	323	8 38·8	−0·7	+0·4	288		H				H		
	8	2825	6·4	2	22·7		S			10 40·5	−2·2	+2·2	228	10 42·6	−1·6	+1·5	247	10 25·1	−1·8	+2·4	228
	18	608	6·0	1	2·8	1 14·8	−0·2	−2·7	125		N				S				N		
	21	1040	6·2	1	5·8	2 49·0	−0·2	−3·4	146		N				G				N		
	22	1158	5·2	1	6·9	3 24·8	−1·4	−0·4	66	3 23·6	−1·3	−1·4	101	3 02·8	−1·8	−0·8	84	3 01·8	−1·8	−1·5	105
	23	1284	6·3	1	8·0		H				H			7 28·0	+0·4	−2·3	141		H		
	24	1386	6·6	1	9·0	5 56·5	−0·1	−2·5	142		N			5 56·5	0·0	−3·5	162		N		
May	3	2441	6·5	2	18·1		N			6 57·4	−1·4	−0·9	315	6 42·1	−0·5	−1·2	333	6 42·9	−1·0	−0·3	309
	3	2448	6·4	2	18·1	8 28·7	·	·	216		N				N				N		
	5	2791	5·4	2	20·2		N				S				N			11 10·3	·	·	335
	15	692	1·1	1	1·2	22 29·7	−1·0	−2·2	115		N			22 11·9	−1·7	−2·6	120		G		
	15	692	1·1	2	1·2	23 31·3	−0·9	0·0	235		N			23 14·5	−1·5	+0·9	225		G		
	19	1114	6·8	1	4·4		N			4 04·3	−0·4	+0·1	56	4 04·9	·	·	28	3 57·5	−0·8	−0·2	61
	20	1238	6·1	1	5·4	3 56·0	+0·2	−2·2	134	4 27·3	·	·	179	3 59·0	+0·2	−3·0	152		N		
	22	1448	6·7	1	7·4	4 33·4	−0·7	−1·1	81	4 40·9	−0·7	−1·6	108	4 21·2	−1·1	−1·5	96	4 26·1	−1·1	−1·8	114
	23	1550	5·8	1	8·4	2 52·4	−1·1	−2·3	133	3 13·7	−0·2	−4·3	171		S				G		
	26	1864	6·8	1	11·5		N				G				N			3 11·5	−3·5	+2·0	67
	26	1869	6·1	1	11·5	5 19·6	−2·0	−0·5	72	5 12·9	−2·1	−1·2	102	4 49·9	−2·2	−0·6	91	4 45·4	−2·2	−1·1	110
	26	1875	6·5	1	11·6	7 29·3	−0·7	−0·3	56	7 29·0	−1·0	−0·9	83	7 14·4	−1·5	−0·5	65	7 12·1	−1·6	−0·9	83
	27	1994	6·5	1	12·6	8 06·4	−0·7	−1·4	94	8 14·4	−0·9	−1·6	114	7 53·9	−1·2	−1·4	97	7 56·9	−1·4	−1·6	110
June	4	3173	5·3	2	20·6	6 53·1	−0·9	+1·7	246		H				H				H		
	22	1821	2·9	1	8·9	4 47·1	·	·	43	4 38·0	−1·6	−0·7	80	4 21·1	−2·1	−0·2	64	4 15·2	−2·1	−0·8	85
	22	1821	2·9	2	8·9	5 11·6	·	·	5	5 38·6	−0·5	−2·6	327	5 09·1	−0·5	−3·3	346	5 23·2	−0·8	−2·7	327
	22	1825	6·1	1	9·0		N			5 58·5	−0·9	+0·3	56		G			5 46·4	−1·7	+0·6	53
	23	1933	7·0	1	9·9	4 33·7	−0·9	−2·8	155		N			4 22·9	−0·6	−3·5	171		N		
	23	1941	4·8	1	10·0		H				N			6 17·9	−0·6	−3·5	169		N		
	25	2167	7·5	1	11·9		N			3 23·3	·		56		N				S		
	30	2987	5·0	2	17·2		S				S				S			11 01·2	−1·2	+0·7	225

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					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
July	5	170	6·2	2	22·2		S			9 59·5	−0·9	+2·6	212	10 11·3	−1·0	+1·8	239	9 56·5	−0·8	+2·0	231
	9	692	1·1	1	26·2	9 47·9	·	·	355		H				N				N		
	9	692	1·1	2	26·2	9 58·2	·	·	335	10 00·1	−0·4	0·0	302		N				N		
	21	2008	6·6	1	8·3	3 40·1	−1·1	−1·8	115	3 50·1	−1·3	−2·3	136	3 22·6	−1·5	−1·8	122	3 27·6	−1·5	−2·2	137
	22	2128	5·8	1	9·4		H			6 04·1	−0·6	−0·2	64		G			5 55·7	−1·1	+0·5	50
	23	2245	6·4	1	10·3	3 27·9	−2·0	0·0	64	3 13·7	−2·4	−0·4	90	2 56·2	−2·4	+0·3	76		S		
	24	2396	6·6	1	11·4	4 13·9	−1·8	−1·6	130	4 20·5	·	·	157	3 49·4	−1·7	−1·3	136	3 52·7	−1·5	−2·4	155
	24	2399	5·0	1	11·4	4 21·2	−1·8	+0·3	55	4 05·1	−2·4	0·0	79	3 51·5	−2·3	+0·7	62	3 38·4	−2·5	+0·4	79
	29	3206	5·2	2	16·4	4 49·4	−1·4	+1·2	260	4 27·7	−1·2	+1·6	241	4 33·1	−0·9	+1·4	259	4 21·4	−0·8	+1·6	245
	31	3526	5·1	2	18·6		S			10 01·6	−2·5	0·0	268		G			9 29·2	−3·3	−1·2	300
Aug.	4	498	6·2	2	22·6	7 54·6	−0·5	+1·4	265	7 39·8	−0·1	+1·4	252	7 49·8	−0·1	+1·1	276		H		
	4	508	4·3	1	22·6	8 42·3	−0·8	+1·5	79	8 25·8	−0·6	+1·0	93	8 35·0	−0·2	+1·7	67	8 25·6	−0·1	+1·4	76
	4	508	4·3	2	22·6	9 52·1	−1·0	+2·0	237	9 26·9	−0·5	+2·3	224	9 39·4	−0·7	+1·7	252	9 27·2	−0·4	+1·7	244
	5	635	3·9	1	23·6	7 31·7	+0·4	+2·3	33		H				H				H		
	5	635	3·9	2	23·6	8 16·9	−0·6	+0·7	294	8 07·4	−0·1	+0·8	277		H				H		
	5	659	6·4	2	23·7		S				S				S			11 11·2	−1·2	+1·3	265
	5	669	4·0	1	23·8		S				S				S			11 43·3	−1·8	+0·4	106
	5	692	1·1	1	23·9	17 22·0	−1·1	−0·5	70	17 22·3	−1·4	−1·7	105	17 02·3	−1·7	−0·4	76	16 59·0	−2·0	−1·1	96
	5	692	1·1	2	23·9	18 29·9	−0·4	−1·6	279	18 33·3	−1·0	−0·1	245	18 20·2	−1·0	−1·2	270	18 19·5	−1·4	−0·2	249
	16	1864	6·8	1	4·6		H				H			2 59·8	−0·6	−1·7	108	3 07·6	−0·6	−1·9	120
	20	2352	6·7	1	8·8		H				H			5 21·7	−0·9	−1·2	88	5 24·6	−1·1	−1·3	99
	23	2825	6·4	1	11·8		N			5 50·3	·	·	18		N				N		
	24	2987	5·0	1	12·9	7 44·4	−1·5	−2·1	118		G			7 22·7	−1·7	−1·1	99	7 21·5	−2·2	−1·4	110
	26	3295	7·0	1	14·8	4 28·3	−1·5	+1·4	59	4 05·4	−1·6	+1·2	74	4 09·1	−1·2	+1·8	53	3 54·8	−1·1	+1·6	64
	31	462	5·9	2	19·9	7 52·3	−1·8	+0·5	286	7 34·5	−1·3	+1·0	272	7 28·5	−1·7	−0·4	309	7 23·0	−1·1	+0·3	296
Sept.	1	608	6·0	2	21·0	10 21·8	−2·0	+0·7	266	9 57·9	−1·8	+1·6	248	9 54·4	−1·8	+0·5	283	9 43·1	−1·6	+1·0	272
	2	741	5·7	2	21·9	8 18·3	−1·2	+0·7	289	8 04·1	−0·7	+1·0	273	8 03·6	−0·9	0·0	308	7 59·5	−0·5	+0·4	295
	15	2167	7·5	1	5·0		H				H				H			2 58·7	−0·9	−0·5	69
	17	2441	6·5	1	7·0		H				H			4 14·5	·	·	25	4 07·1	−0·7	+0·6	45
	18	2571	6·9	1	7·9	1 35·3	·	·	34	1 10·7	−2·5	+0·9	60		S				S		
	20	2902	6·0	1	10·0	1 29·4	−2·0	+0·4	80	1 11·3	−2·2	+0·2	98		S				S		
	22	3206	5·2	1	12·0	1 15·4	−1·4	+1·4	67	0 54·5	−1·2	+1·0	85		S				S		
	27	405	4·4	1	17·1	4 52·2	−0·6	+2·1	46	4 30·7	−0·5	+1·7	59	4 46·6	−0·1	+2·4	32	4 33·5	−0·1	+2·1	42
	27	405	4·4	2	17·1	5 57·8	−1·5	+1·1	266	5 36·8	−1·1	+1·4	253	5 38·5	−1·2	+0·9	283	5 29·0	−0·9	+1·0	273
	29	677	4·8	2	19·1	4 02·2	−0·4	+0·2	308		H				N				N		
	29	682	6·0	2	19·1	4 25·8	+0·5	+2·8	203		N				H				H		
	29	685	6·5	2	19·1	5 36·1	−0·8	+0·9	284	5 23·1	−0·4	+1·0	269	5 26·8	−0·5	+0·5	300		H		
	29	692	1·1	1	19·2	5 54·4	−0·1	+2·6	36	5 33·2	0·0	+1·9	52	5 56·1	+0·5	+3·2	17	5 41·7	+0·4	+2·5	31
	29	692	1·1	2	19·2	6 49·9	−1·5	+0·5	289	6 34·0	−1·0	+1·0	272	6 30·5	−1·3	−0·2	310	6 25·7	−0·8	+0·3	296
	30	814	5·3	2	20·1	5 31·7	−0·3	+1·2	273		H				H				H		
	30	836	5·5	2	20·3		N			8 32·8	·	·	315		N				N		
Oct.	3	1236	5·1	2	23·4		N			10 19·0	−2·1	−2·7	329		N				N		
	4	1336	5·2	2	24·3	8 30·7	0·0	+2·0	248		H				H				H		
	4	1337	5·6	2	24·3	8 34·3	−0·5	−0·2	314		H				H				H		
	14	2396	6·6	1	4·2		H			1 35·6	−1·3	−2·0	124	1 12·2	−1·4	−1·3	99	1 14·0	−1·7	−1·5	110
	14	2399	5·0	1	4·2		N			1 48·2	−0·5	+0·6	47		N				G		
	16	2710	6·8	1	6·3		H				H			3 39·7	−0·9	−0·8	76	3 40·4	−1·2	−0·9	86
	18	3011	7·0	1	8·4		N			4 29·2	·	·	3		N				N		
	18	3022	6·9	1	8·4		H				H			5 29·1	−1·0	−1·2	93	5 31·9	−1·5	−1·6	105
	19	3173	5·3	1	9·5		H			6 41·5	−0·8	−1·1	93	6 31·4	−0·6	−0·2	57	6 29·8	−0·9	−0·3	69
	20	3310	6·4	1	10·3	2 25·1	−1·6	+1·0	56	2 02·6	−2·0	+1·1	68	2 03·2	−1·4	+1·7	43	1 47·1	−1·6	+1·7	52
	20	3324	7·2	1	10·5	6 53·9	−0·5	−0·1	53	6 51·2	−1·0	−0·4	75	6 46·3	−0·6	+0·6	38	6 40·0	−1·0	+0·4	51
	21	3463	6·4	1	11·4	3 51·1	−2·1	−0·1	88	3 35·3	−2·8	−0·4	102	3 24·0	−1·7	+1·0	71	3 10·9	−1·9	+1·0	78
	26	608	6·0	2	16·4	4 00·1	−0·6	+1·8	246	3 40·4	−0·2	+1·9	232	3 52·7	−0·3	+1·4	259	3 43·6	−0·1	+1·5	251
Nov	3	1609	4·7	2	24·6	9 27·0	−0·5	+1·2	274		H				H				H		
	11	2497	6·6	1	2·6		H			0 23·3	−1·0	−1·0	92		S				S		
	14	2959	7·2	1	5·6	0 32·8	−0·8	+1·3	28	0 13·5	−1·7	+1·2	45	0 23·4	·	·	3		S		
	17	3422	6·7	1	8·8	5 54·5	−0·3	+0·6	37	5 48·5	−0·8	0·0	61	5 49·6	−0·4	+1·4	23	5 40·9	−0·8	+0·9	38
	19	170	6·2	1	10·9		H				N			8 41·0	−1·0	−4·6	133		N		
	21	405	4·4	1	12·7	0 19·5	−0·3	+1·9	53	0 02·0	−0·2	+1·5	66	0 16·9	+0·1	+2·0	43		H		
	23	692	1·1	1	14·7	0 49·1	0·0	+1·4	81	0 39·4	+0·1	+0·8	95	0 50·6	+0·3	+1·4	71		H		
	23	692	1·1	2	14·7	1 47·5	−0·3	+1·7	246	1 31·0	+0·1	+1·8	232	1 44·8	0·0	+1·4	258	1 37·2	+0·2	+1·4	250
	24	832	4·7	2	15·7	2 12·8	−0·9	−0·1	311	2 06·7	−0·3	+0·4	291		H				H		
	24	836	5·5	2	15·7	2 58·9	−0·7	+1·1	277	2 44·9	−0·3	+1·2	262	2 50·6	−0·4	+0·7	292	2 45·2	−0·2	+0·8	281
	28	1375	5·6	2	20·0	10 07·0	−2·8	+2·4	241		N			9 32·0	−1·9	+3·9	230		N		
	29	1466	5·2	2	20·9	6 42·1	−0·4	+2·0	254		H			6 38·2	0·0	+1·6	260		H		
	29	1487	1·3	1	21·1	12 52·6	·	·	48	12 24·7	−2·8	−0·5	98	12 06·9	−2·7	+1·0	77	11 54·3	−2·5	−0·2	102
	29	1487	1·3	2	21·1	13 25·4	·	·	3	13 53·2	−1·4	−2·5	317	13 20·0	−1·2	−3·0	332	13 27·6	−1·9	−2·0	308
Dec.	13	3222	7·1	1	5·1		N			2 20·5	·	·	351		N				N		
	13	3231	7·4	1	5·1		H			3 18·1	−0·7	−0·4	72	3 15·1	−0·3	+0·6	35	3 10·4	−0·7	+0·4	49

Date	Z.C. No.	Mag.	Ph.	Age of Moon	F ILLINOIS W. 91°·000, N. 40°·000 U.T.	*a*	*b*	*P*	G TEXAS W. 98°·000, N. 31°·000 U.T.	*a*	*b*	*P*	H DENVER, COLO. W. 104°·950, N. 39°·677 U.T.	*a*	*b*	*P*	I N. MEX.–ARIZ. W. 109°·000, N. 34°·000 U.T.	*a*	*b*	*P*
				d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Dec. 14	3375	6·9	1	6·1	3 34·9	−0·5	0·0	52	3 31·4	−1·0	−0·4	74	3 26·8	−0·6	+0·7	37	3 19·9	−1·1	+0·5	50
16	95	7·1	1	8·1	2 18·6	−0·8	+2·3	19	1 51·9	−1·5	+2·0	36		G			1 49·4	·	·	3
17	249	4·7	1	9·2		N			4 33·2	−1·0	+2·8	18		N				N		
17	364	4·3	1	10·1	24 05·3	·	·	132		N			23 40·0	−1·1	+0·8	108		S		
19	491	6·2	1	11·1	1 36·0	−2·4	−0·4	116		N			1 10·9	−1·3	+1·0	95	1 00·8	−1·3	+0·6	105
20	667	5·3	1	12·3	8 02·2	−1·0	−2·4	117		N			7 44·3	−1·7	−2·6	121		G		
20	692	1·1	1	12·5		H				N			11 45·8	+0·5	−3·0	140		N		
20	692	1·1	2	12·5		H				N			12 18·4	−0·3	+0·8	212		N		
24	1236	5·1	2	16·5		S				S			13 29·1	−0·9	−0·6	248	13 21·2	·	·	217
26	1434	5·6	2	18·3		N			7 36·8	−1·9	−1·8	320		N			7 12·2	−1·5	−2·4	333
31	1950	5·8	2	23·4	9 11·5	−1·0	+1·1	275	8 40·3	·	·	219		H				H		

Date	Z.C. No.	Mag.	Ph.	Age of Moon	J EDMONTON, ALTA. W. 113°·075, N. 53°·533 U.T.	*a*	*b*	*P*	K CALIFORNIA W. 120°·000, N. 36°·000 U.T.	*a*	*b*	*P*	L OREGON W. 121°·000, N. 42°·500 U.T.	*a*	*b*	*P*	M VANCOUVER, B.C. W. 123°·100, N. 49°·500 U.T.	*a*	*b*	*P*
				d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Jan. 6	1525	5·9	2	19·0	10 09·4	−2·0	+1·8	243		N				N				N		
21	3537	6·8	1	4·2	3 25·3	−0·9	−2·4	112		N				N			3 24·8	−1·4	−2·9	120
23	249	4·7	1	6·2	0 32·0	−1·7	+0·1	96		N				S				S		
24	398	6·7	1	7·4		N			7 09·0	−0·7	−0·4	67	7 07·9	−0·7	+0·3	43	7 14·6	·	·	9
24	401	6·3	1	7·4		N			7 42·7	−0·7	+2·0	22		N				N		
25	491	6·2	1	8·2	1 53·0	−2·0	−0·8	119		N				N						
25	516	7·3	1	8·4		N			8 01·8	−0·8	+0·6	44		G			1 34·7	−2·1	−0·4	120
26	626	6·4	1	9·2	2 40·0	−1·5	+0·7	82	2 31·4	·	·	138	2 20·6	−2·2	0·0	107		N		
26	635	3·9	1	9·3	5 19·3	−1·3	−0·6	80		N			5 18·8	−2·2	−2·2	116	2 21·2	−1·5	+1·1	84
26	659	6·4	1	9·4	8 48·2	−0·5	−0·4	48	9 03·7	−0·3	−1·7	106	8 53·7	−0·5	−1·2	86	5 06·1	−1·7	−0·5	90
26	661	4·6	1	9·5	9 10·9	+0·2	−2·9	134		N				N			8 45·1	−0·7	−0·8	67
26	669	4·0	1	9·5		H				H				H				N		
26	671	3·6	1	9·5		H				H				H			10 13·9	−0·1	−1·1	76
28	934	6·4	1	11·5	11 11·1	−0·2	−1·1	66	11 34·4	+0·2	−1·7	113	11 24·2	−0·1	−1·5	97	10 15·8	0·0	−1·6	97
29	1040	6·2	1	12·3	2 43·7	−0·9	+1·9	71	2 15·3	−1·3	+0·2	117	2 19·0	−0·9	+1·2	95	11 13·9	−0·3	−1·3	83
29	1072	6·2	1	12·6	11 48·5	0·0	−1·8	106		H			12 12·2	+0·3	−2·4	137	2 28·3	−0·6	+1·9	75
30	1158	5·2	1	13·3		N			3 28·9	−0·9	+2·5	59	3 50·9	·	·	28	11 56·6	0·0	−2·1	122
Feb. 3	1600	5·1	2	17·5	10 54·3	−2·1	+0·4	241		N				N				N		
6	1924	5·8	2	20·6		N			11 04·7	·	·	6		N				N		
10	2441	6·5	2	24·6	12 41·3	−0·9	+0·6	294	12 13·9	−1·6	+2·0	245	12 23·0	−1·2	+1·3	264		H		
21	462	5·9	1	5·8	3 47·5	−1·0	−1·8	102		N				N			3 44·0	−1·4	−2·3	115
22	608	6·0	1	6·9	7 16·6	−0·6	+0·7	25	7 21·8	−0·3	−1·1	89	7 15·3	−0·4	−0·7	69	7 10·6	−0·6	−0·2	48
23	741	5·7	1	7·9		N			6 47·4	−1·2	−0·1	62	6 48·4	−1·4	+1·0	37		N		
24	878	5·5	1	8·9	6 07·0	−0·8	−2·6	125		N				N			6 12·1	·	·	148
26	1116	7·4	1	10·8	3 00·3	·	·	156		N				N				N		
26	1141	5·6	1	11·0	8 41·5	·	·	166		N				N				N		
27	1235	7·4	1	11·8	2 01·6	−1·1	+0·3	122		N				N				S		
27	1238	6·1	1	11·8	3 05·4	·	·	32	2 16·5	−1·3	+0·8	98	2 24·2	−1·1	+1·8	76	2 39·6	−0·8	+3·3	49
27	1247	6·8	1	11·9	6 56·6	−1·7	−0·1	69	7 02·5	−1·8	−2·3	127	6 49·4	−1·9	−1·2	108	6 40·1	−1·8	−0·3	89
27	1258	6·7	1	12·0		N			9 25·9	−2·0	+0·5	54		N				N		
Mar. 1	1442	Var.	1	13·8	1 44·9	−0·6	−0·8	154		N				N				S		
5	1875	6·5	2	17·9	6 23·6	−0·5	−0·2	322	6 06·0	−1·0	+1·8	258	6 13·6	−0·7	+1·0	281	6 17·3	−0·5	+0·5	302
6	1994	6·5	2	19·0	7 54·0	−1·1	+1·2	273		N				N			7 35·9	−1·1	+2·3	250
8	2245	6·4	2	21·1	10 23·2	−0·8	−0·3	323	10 12·2	−1·7	+0·8	274	10 14·6	−1·2	+0·4	290	10 15·0	−0·9	+0·3	304
9	2399	5·0	2	22·2	12 02·5	−1·3	+0·2	289	11 38·0	−2·3	+1·7	246	11 44·4	−1·8	+1·0	263	11 47·4	−1·3	+0·8	275
11	2715	6·5	2	24·2		N			13 18·2	−1·5	−0·2	303	13 14·7	−1·0	−0·5	320	13 07·6	·	·	340
14	4001	0·7	1	27·5	20 37·1	−1·3	−1·8	109		N				G			20 28·1	−1·7	−1·4	107
14	4001	0·7	2	27·5	21 28·3	−0·2	+0·3	209		N				G			21 23·0	−0·4	+0·7	208
21	526	6·9	1	4·3	2 32·3	−1·0	+2·1	19		S				S				S		
22	682	6·0	1	5·3	2 25·6	−1·1	−3·3	134		N				N				N		
22	685	6·5	1	5·3	3 37·2	−1·2	+1·5	26	3 30·4	−1·5	−1·2	93	3 23·8	−1·5	−0·4	71	3 21·2	−1·4	+0·6	47
22	692	1·1	1	5·4		N			4 56·0	−1·0	−0·1	61	4 57·1	−1·2	+1·0	36		N		
22	692	1·1	2	5·4		N			5 55·7	−0·1	−1·9	293	5 39·8	0·0	−3·2	316		N		
22	699	5·8	1	5·4	5 44·9	+0·1	−2·5	126		N				N			6 00·2	·	·	153
23	806	5·1	1	6·3	2 46·8	−1·2	−3·2	137		N				N				N		
23	814	5·3	1	6·4		N			4 31·8	−1·7	+0·1	62	4 35·2	−1·8	+1·8	35		N		
24	951	6·8	1	7·3	2 27·8	−1·6	+0·5	67		N				S				S		
26	1210	5·9	1	9·4	5 54·5	−0·6	−2·8	141		N				N			6 04·4	·	·	170
28	1413	6·7	1	11·4	3 12·1	·	·	41		S				S				S		
28	1439	5·9	1	11·6		N			10 50·2	−0·8	+0·3	49		N				N		

Date		Z.C. No.	Mag.	Ph.	Age of Moon	J EDMONTON, ALTA. W. 113°075, N. 53°533				K CALIFORNIA W. 120°000, N. 36°000				L OREGON W. 121°000, N. 42°500				M VANCOUVER, B.C. W. 123°100, N. 49°500			
						U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Mar.	28	1441	6·4	1	11·6		H				H			11 07·6	−0·2	−1·2	80	10 58·9	−0·4	−1·1	68
	28	1442	Var.	1	11·6		H				H			11 12·7	0·0	−1·7	109	11 00·8	−0·2	−1·7	99
Apr.	4	2223	4·0	1	18·7		S			13 01·4	−1·8	−0·6	81	12 56·6	−1·7	−0·3	67	12 51·7	−1·6	0·0	53
	8	2825	6·4	2	22·7		H			10 12·2	−1·5	+2·8	222		H				H		
	18	626	6·4	1	2·9		H				H				H			4 42·5	+0·1	−1·8	107
	23	1284	6·3	1	8·0	6 58·9	−0·1	−2·1	121	7 46·8	·	·	174	7 24·9	+0·2	−2·8	151	7 06·4	−0·2	−2·4	136
	24	1386	6·6	1	9·0	5 13·2	−0·8	−2·3	136		N				G			5 17·3	−0·5	−3·3	158
	26	1600	5·1	1	11·1	8 22·2	−0·2	−2·6	158		N				N			8 34·3	·	·	179
May	3	2441	6·5	2	18·1		N			6 33·9	−0·7	+0·2	301	6 33·5	−0·3	−0·2	319		H		
	3	2448	6·4	2	18·1	8 04·4	−1·7	+1·7	231		N				N				N		
	5	2798	6·3	2	20·3		S			11 35·1	·	·	195		S				S		
	15	692	1·1	1	1·2	21 44·1	−1·4	0·0	72	21 51·1	·	·	136	21 34·5	−2·2	−1·0	105	21 28·2	−1·7	+0·2	81
	15	692	1·1	2	1·2	22 59·3	−1·2	−1·1	269	22 39·3	·	·	202	22 50·8	−1·7	+0·9	233	22 48·9	−1·5	−0·3	257
	19	1114	6·8	1	4·4		N			3 46·1	−1·2	−0·5	69		S				N		
	19	1124	6·9	1	4·5		N			5 17·1	−0·4	−0·4	64	5 15·3	−0·8	+0·2	44		N		
	20	1247	6·8	1	5·5		H				N				H			6 49·9	+0·5	−2·5	149
	22	1448	6·7	1	7·4		S			4 08·6	−1·4	−2·1	124	3 55·2	−1·5	−1·6	109		S		
	26	1869	6·1	1	11·5	4 32·0	−2·0	+0·5	69	4 20·6	−1·9	−1·0	121	4 14·6	−1·9	−0·3	106		S		
	26	1875	6·5	1	11·6		N			6 50·0	−2·1	−0·9	90	6 43·6	−2·1	−0·4	76	6 37·7	−2·2	+0·1	*61
	27	1994	6·5	1	12·6	7 27·1	−1·3	−1·0	80	7 36·7	−1·7	−1·5	113	7 26·5	−1·7	−1·1	102	7 16·3	−1·6	−0·8	92
June	18	1422	6·8	1	5·0	5 17·0	−0·1	−1·4	74		H			5 31·6	−0·1	−1·5	96	5 20·8	−0·3	−1·5	86
	21	1732	7·0	1	8·0		H			7 16·4	−0·1	−2·7	152	7 00·4	−0·3	−2·3	139	6 44·3	−0·4	−2·1	128
	22	1821	2·9	1	8·9		N			3 48·5	−2·4	−0·8	96		S				S		
	22	1821	2·9	2	8·9		N			5 07·0	−1·2	−2·4	321	4 49·6	−0·9	−2·6	334	4 29·2	−0·5	−2·8	348
	22	1825	6·1	1	9·0		N			5 24·9	−2·4	+0·2	62		N				N		
	23	1941	4·8	1	10·0	5 35·9	−0·8	−2·0	145		N			5 57·9	·	·	175	5 36·1	−0·8	−2·3	160
	30	2981	5·2	2	17·2	9 39·7	−0·8	+1·3	198		N				N			9 23·9	·	·	196
	30	2987	5·0	2	17·2		S			10 45·7	−1·7	+0·4	243	10 44·9	−1·7	−0·1	258	10 40·1	−1·5	−0·3	271
July	2	3307	4·9	2	19·2		S			11 41·1	−2·3	0·0	271		S				S		
	5	170	6·2	2	22·2		S			9 52·4	−0·6	+1·7	243	10 02·6	−0·6	+1·6	255	10 12·3	−0·6	+1·5	267
	22	2128	5·8	1	9·4		N			5 41·3	·	·	45		N				N		
	24	2399	5·0	1	11·4	3 51·5	·	·	31	3 13·9	−2·1	+0·7	86		S				S		
	26	2734	5·4	1	13·5	6 29·8	−1·5	−0·9	137		N				G			6 18·5	−1·5	−0·9	144
Aug.	3	405	4·4	1	21·7		S			11 46·0	−1·5	+1·7	64	11 56·9	−1·1	+2·1	48		S		
	4	508	4·3	1	22·6	9 02·6	+0·1	+2·3	37		H				H			8 55·1	+0·2	+2·1	37
	4	508	4·3	2	22·6	9 53·8	−0·7	+1·3	285	9 26·5	−0·2	+1·4	258	9 35·0	−0·4	+1·3	272	9 43·0	−0·4	+1·2	287
	5	659	6·4	2	23·7		N			11 01·9	−0·9	+0·8	285	11 04·3	−1·2	+0·2	305		N		
	5	661	4·6	2	23·7		S			10 58·8	+0·6	+4·0	191	11 19·6	−0·1	+2·7	215	11 35·9	−0·3	+2·2	233
	5	669	4·0	1	23·8		S			11 30·8	−0·9	+1·3	86	11 40·3	−0·7	+1·8	70	11 53·3	−0·4	+2·2	53
	5	669	4·0	2	23·8		S			12 42·1	−1·1	+2·1	237		S				S		
	5	671	3·6	1	23·8		S			11 35·8	−1·3	+0·5	109	11 41·0	−0·9	+1·3	91	11 50·4	−0·6	+1·8	74
	5	671	3·6	2	23·8		S			12 33·7	−0·6	+3·0	213		S				S		
	5	692	1·1	1	23·9	17 01·0	·	·	21	16 33·1	−2·3	−0·3	86	16 32·7	−1·9	+0·8	64	16 38·3	−1·4	+2·0	37
	5	692	1·1	2	23·9	17 39·9	·	·	320	18 01·3	−1·8	−0·1	252	17 55·1	−1·7	−1·2	275	17 39·5	−1·5	−2·4	300
	16	1869	6·1	1	4·7		H				N				N			4 08·2	−0·3	−2·9	165
	17	1978	6·6	1	5·7		N			4 42·2	−0·7	+0·6	48		N				N		
	20	2352	6·7	1	8·8		H			5 07·2	−1·6	−1·0	91	5 00·1	−1·5	−0·7	77	4 52·6	−1·3	−0·6	65
	21	2497	6·6	1	9·8	5 27·9	−1·2	−1·8	134		N			5 40·7	·	·	156	5 21·1	−1·5	−1·7	138
	24	2981	5·2	1	12·8	6 26·3	·	·	140		N				N			6 12·1	·	·	140
	24	2987	5·0	1	12·9	7 04·0	−1·1	−0·2	65	6 56·3	−2·1	−0·3	91	6 53·7	−1·7	0·0	77	6 51·5	−1·4	+0·3	64
	26	3295	7·0	1	14·8	4 28·1	−0·8	+2·0	28	3 47·8	−0·8	+1·7	61	3 59·1	−0·7	+2·0	47		H		
	28	76	5·9	2	17·0		S			12 20·2	−1·1	+1·1	219		S				S		
	31	462	5·9	2	19·9		N			7 09·6	·	·	324		N				N		
Sept.	1	608	6·0	2	21·0		N			9 28·2	−1·4	+0·3	294	9 24·0	·	·	324		N		
	5	1158	5·2	2	25·1		S				N				N			11 56·1	+0·4	+4·3	208
	15	2167	7·5	1	5·0		N			2 45·8	−1·4	−0·2	62	2 45·5	·	·	41		N		
	17	2441	6·5	1	7·0		N			4 02·1	·	·	24		N				N		
	20	2908	6·9	1	10·0	2 54·5	−1·5	−0·5	137		N				N				S		
	27	405	4·4	1	17·1		N				H			4 56·6	+0·4	+3·2	7		N		
	27	405	4·4	2	17·1		N			5 22·0	−0·6	+0·6	290	5 23·6	−0·9	−0·1	311		N		
	29	692	1·1	1	19·2		N			5 55·1	·	·	6		N				N		
	29	692	1·1	2	19·2		N			6 15·5	·	·	323		N				N		
	29	699	5·8	2	19·2	7 34·3	+0·4	+3·8	191		N				N			7 24·3	+0·5	+3·4	193
Oct.	16	2710	6·8	1	6·3		H			3 24·8	−1·4	−0·3	71	3 22·3	−1·2	−0·1	55	3 20·7	−0·9	+0·2	37
	18	3022	6·9	1	8·4	5 11·9	−0·6	−0·4	51	5 12·8	−1·6	−0·6	84	5 08·5	−1·2	−0·3	67	5 05·1	−0·9	0·0	50
	19	3167	7·1	1	9·4		G				N				N			4 12·3	·	·	140
	19	3173	5·3	1	9·5		H			6 19·2	−1·0	+0·4	49	6 22·9	−0·5	+1·0	27		C		
	19	3177	6·0	1	9·5		H				N				N			6 45·4	−1·5	−1·9	114
	20	3310	6·4	1	10·3	2 23·3	·	·	7		S			1 49·4	−1·1	+2·5	27	2 05·9	·	·	8
	20	3324	7·2	1	10·5		N			6 31·3	−0·8	+1·4	28	6 44·9	·	·	358		N		

Date		Z.C. No.	Mag.	Ph.	Age of Moon	J EDMONTON, ALTA. W. 113°.075, N. 53°.533				K CALIFORNIA W. 120°.000, N. 36°.000				L OREGON W. 121°.000, N. 42°.500				M VANCOUVER, B.C. W. 123°.100, N. 49°.500			
						U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Oct.	20	3332	7.2	1	10.5	8 05.7	−0.7	−1.2	84		N			8 15.7	−1.4	−2.2	112	8 02.3	−1.0	−1.1	86
	21	3463	6.4	1	11.4	3 31.4	−0.9	+1.5	40	2 55.4	−1.4	+1.5	64	3 05.0	−1.2	+1.7	51	3 15.5	−0.9	+1.8	39
	26	608	6.0	2	16.4	4 07.7	−0.4	+1.2	292		H			3 53.2	0.0	+1.1	278	4 00.4	−0.1	+1.0	293
	26	626	6.4	2	16.6	8 07.6	−0.8	+2.5	213		N			7 24.1	.	.	179	7 49.9	−0.6	+2.7	212
	26	635	3.9	1	16.6	9 37.7	−1.9	−2.0	128		N				N			9 25.3	.	.	137
	26	635	3.9	2	16.6	10 23.9	−1.1	+2.6	203		N				N			10 00.4	.	.	191
	26	659	6.4	2	16.7		S				N				N			13 31.0	.	.	198
	28	943	6.2	2	18.7	12 43.3	.	.	209		N				N				N		
	28	947	5.2	2	18.7		G				S			13 46.2	−1.6	−1.7	291	13 27.1	−1.3	−3.0	316
Nov.	15	3118	6.9	1	6.7	1 50.2	−1.7	−0.8	114		N			1 44.8	.	.	131	1 34.3	−1.8	−0.3	112
	17	3421	5.1	1	8.8	4 55.8	−1.2	−0.8	85		N			4 53.2	−2.2	−1.3	106	4 44.2	−1.5	−0.3	84
	17	3422	6.7	1	8.8		N			5 37.1	−0.3	+2.5	12		N				N		
	18	36	7.2	1	9.9		N			9 02.2	−0.5	+0.1	53	9 04.9	−0.3	+0.9	27		N		
	18	37	7.5	1	9.9		H			9 10.9	−0.6	−1.3	94	9 04.1	−0.5	−0.7	70	9 00.4	−0.4	−0.1	46
	19	165	6.7	1	10.9	6 40.3	−1.5	−1.6	107		N				N			6 29.0	−2.0	−1.4	109
	19	170	6.2	1	10.9	8 08.0	−0.8	−0.8	72		G			8 12.6	−1.5	−1.8	104	8 01.7	−1.1	−0.7	78
	19	178	6.8	1	10.9	9 09.8	−0.6	−2.2	109		N				N			9 12.2	−1.1	−3.1	122
	21	405	4.4	1	12.7	0 50.6	+0.3	+2.7	9		H				H				H		
	23	692	1.1	1	14.7	1 16.6	+0.4	+1.9	43		H				H				H		
	23	692	1.1	2	14.7	2 01.9	−0.1	+1.2	289		H			1 49.6	+0.2	+1.0	276	1 57.1	+0.1	+1.0	290
	27	1262	6.2	2	19.0	9 54.0	−1.4	+1.7	249		N				N			9 31.4	−1.1	+2.9	235
	28	1371	6.4	2	19.9	7 59.8	−0.6	+1.9	262		N			7 30.5	+0.1	+3.2	227	7 47.9	−0.2	+2.0	254
	28	1375	5.6	2	20.0	9 44.7	−1.2	+0.8	281		G			9 17.6	−1.0	+2.5	245	9 29.0	−1.0	+1.5	270
	29	1487	1.3	1	21.1		N			11 29.5	−2.0	+0.2	104	11 33.1	−1.9	+1.5	81	11 46.1	.	.	51
	29	1487	1.3	2	21.1		N			13 01.5	−2.2	−1.2	300	12 49.8	−1.6	−1.9	320	12 29.7	.	.	348
Dec.	13	3231	7.4	1	5.1		N			3 04.8	−0.5	+1.4	25		G				N		
	14	3375	6.9	1	6.1		N			3 11.1	−0.8	+1.6	27	3 26.0	.	.	356		N		
	17	364	4.3	1	10.1	23 53.2	−0.4	+1.7	77		S				S				S		
	18	405	4.4	1	10.4	9 33.0	−0.3	−0.9	67	10 02.4	−0.1	−4.1	137	9 44.6	−0.5	−1.9	105	9 32.9	−0.6	−1.2	81
	19	491	6.2	1	11.1	1 25.8	−0.5	+1.9	61		S				S			1 14.0	−0.3	+1.9	59
	19	498	6.2	1	11.2	3 07.7	−1.4	+0.7	101		N			2 50.0	−2.0	−0.1	120	2 50.9	−1.2	+1.0	99
	19	508	4.3	1	11.2	5 31.1	.	.	140		N				N				G		
	20	635	3.9	1	12.2	2 14.0	−0.8	+1.2	101		N			1 56.4	−0.9	+0.5	118	2 01.7	−0.6	+1.3	99
	20	667	5.3	1	12.3	7 16.8	−1.3	0.0	71	7 22.9	.	.	135	7 06.9	−2.2	−0.9	103	7 01.2	−1.6	+0.3	79
	20	677	4.8	1	12.4	8 40.9	−1.0	−3.9	138		N				N				N		
	20	692	1.1	1	12.5	11 15.8	−0.2	−1.8	99		N			11 42.6	+0.3	−4.3	147	11 21.1	−0.4	−2.4	118
	20	692	1.1	2	12.5	12 12.7	−0.1	−1.0	248		N			12 11.5	−0.9	+1.7	203	12 13.0	−0.5	−0.3	230
	24	1236	5.1	2	16.5	13 05.9	−0.8	−1.5	272		N			13 05.2	−2.0	+0.5	233	13 00.0	−1.4	−0.7	253
	24	1241	6.4	2	16.5	14 04.5	−0.2	−2.2	304		S			14 21.8	−0.7	−1.5	275	14 08.8	−0.6	−1.8	287
	26	1434	5.6	2	18.3		N			6 48.8	.	.	356		N				N		
	29	1749	6.1	2	21.5	13 11.0	−1.9	+0.2	262		N				N			12 41.3	.	.	230

How to Use the Prediction Tables

Universal time is Greenwich time, counted from 0 to 24 hours, beginning at midnight; times greater than 12:00 are p.m. To convert to standard times in the United States and Canada, subtract the following number of hours: for AST, 4; EST, 5; CST, 6; MST, 7; and for PST, 8. If necessary, add 24 hours to the UT before subtracting, and use the previous calendar date.

Consider, for an example, the last line of the table, December 29, 1961, for the star Z.C. 1749. It is of magnitude 6.1; the phenomenon is a reappearance (at the moon's dark western edge), the moon's age being 21.5 days. The table on the first page of the supplement identifies this star also as 10 Virginis.

The next column states that at standard station **J** (LoS +113°.075, LS +53°.533, at Edmonton, Alberta) the reappearance will occur at 13:11.0 UT. The corresponding Mountain standard time (MST) is 6:11.0 a.m.

Suppose an observer is near Calgary, Alberta, at Lo +114°.0, L +50°.5. The **a** quantity for **J** is −1.9 and **b** is +0.2. The correction to the standard-station time is, therefore, $-1.9(114.0 - 113.1) + 0.2(50.5 - 53.5) = -2.3$ minutes. Hence the reappearance at Calgary is due at 6:11.0 − 2.3, or at 6:08.7 a.m. MST on December 29th.

The table also tells that at Edmonton the point of reappearance of the star on the moon's edge will be 262° from the north point, counted eastward around the limb. This same angle will hold roughly for Calgary.

Mrs. Sadler points out that an observer located between two standard stations can often make more accurate predictions by replacing the **a** and **b** of the nearer station by **a′** and **b′**, found as follows. First compute the interpolation factor **q**:

$$\mathbf{q} = \frac{L - LS_1}{2(LS_2 - LS_1)},$$

where the subscripts 1 and 2 indicate the nearer and farther standard station, respectively. Then **a′** and **b′** are given by:

$$\mathbf{a'} = \mathbf{a}_1 + \mathbf{q}(\mathbf{a}_2 - \mathbf{a}_1),$$
$$\mathbf{b'} = \mathbf{b}_1 + \mathbf{q}(\mathbf{b}_2 - \mathbf{b}_1).$$

For example, an observer at Norman, Oklahoma (Lo +97°.4, L +35°.2), is nearer station **G** (LoS_1 +98°.0, LS_1 +31°.0) than station **H** (LoS_2 +104°.9, LS_2 +39°.7). He would find

$$\mathbf{q} = \frac{35.2 - 31.0}{2(39.7 - 31.0)} = +0.24.$$

New factors may then be formed for all occultations listed for both **G** and **H**. Thus, in the case of Z.C. 741 on February 23rd:

$$\mathbf{a'} = -0.4 + 0.24(-1.0 + 0.4) = -0.5,$$
$$\mathbf{b'} = 0.0 + 0.24(+1.3 - 0.0) = +0.3.$$

Then **a′** and **b′** can be used, just as **a** and **b** in the previous example, to convert the station **G** prediction to that for the observer at Norman.

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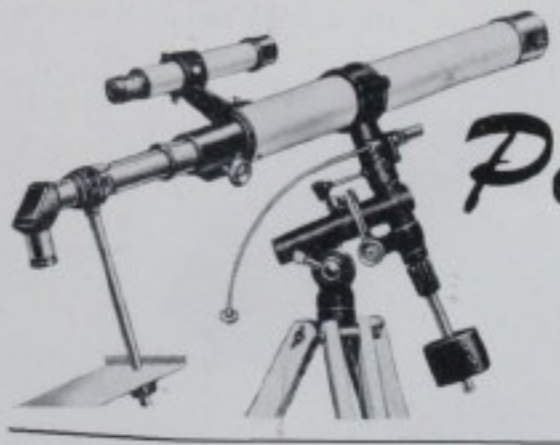

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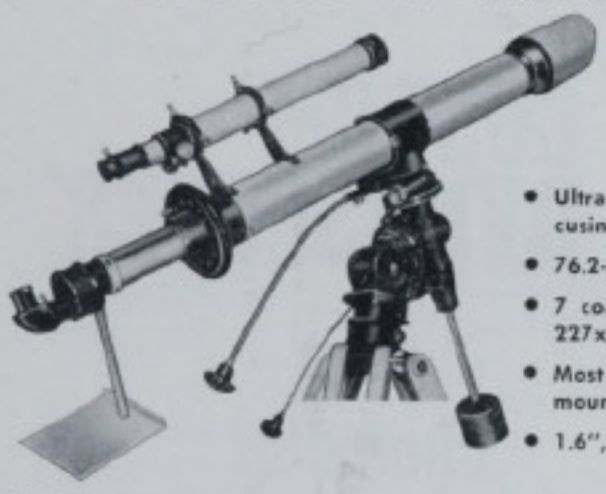

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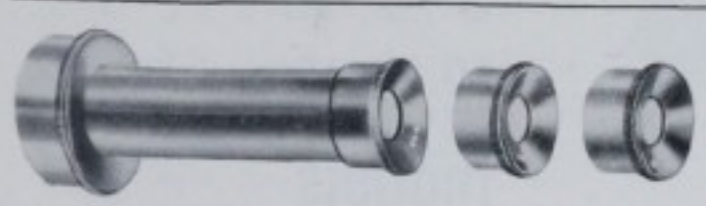

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BOOKS AND THE SKY

THE PLANETARY EQUATORIUM OF JAMSHID GHIYATH AL-DIN AL-KASHI

E. S. Kennedy, translator. Princeton University Press, Princeton, N. J., 1960. 267 pages. $7.50.

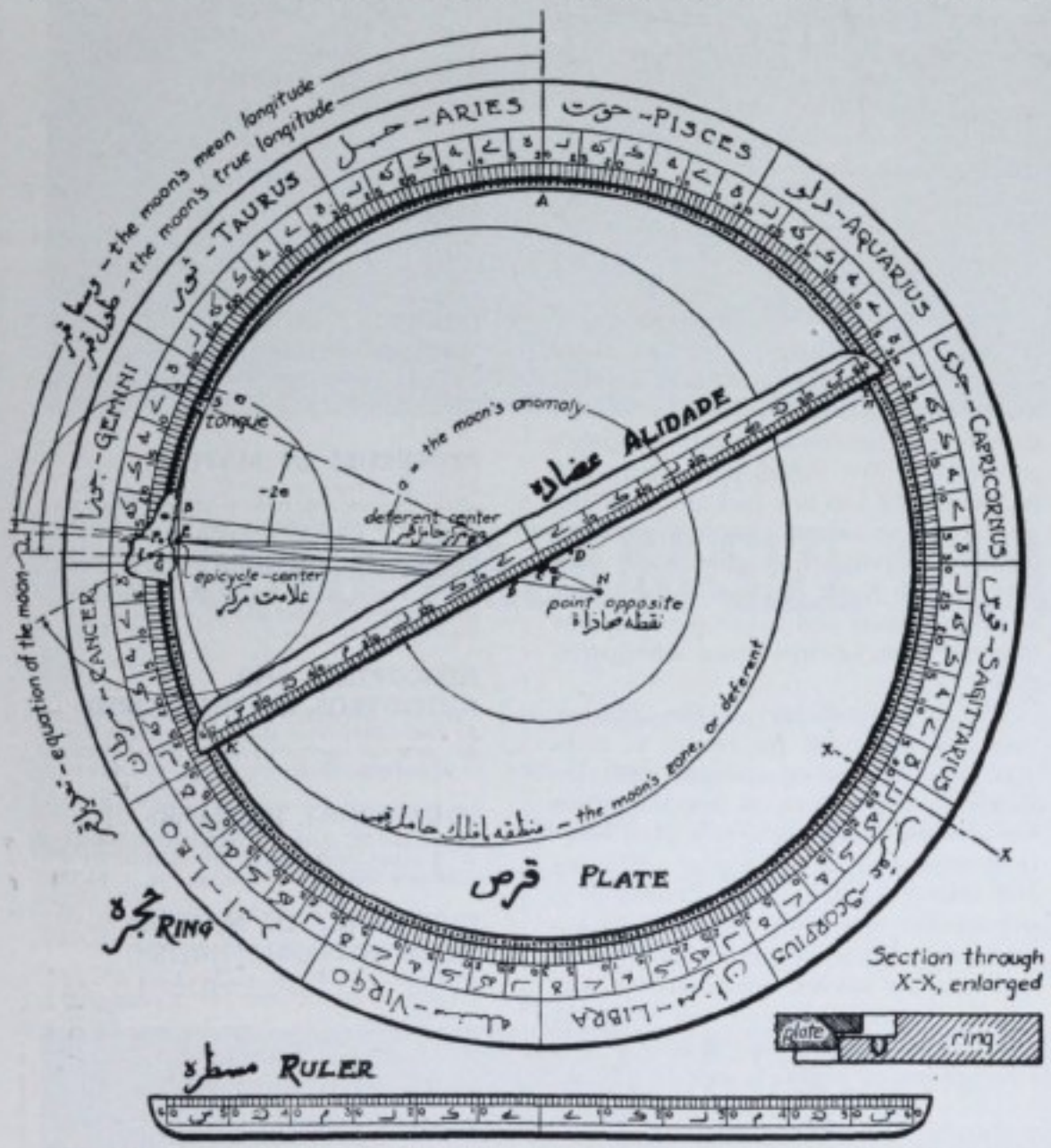
THIS book concerns an anonymous Persian manuscript, written about A.D. 1500, which is now at Princeton University. The manuscript is an abridged translation or paraphrase of an earlier Arabic work by Jamshid Ghiyath al-Din al-Kashi, describing in detail an equatorium he devised. This type of mechanical contrivance was used by medieval astronomers, both European and Moslem, to predict the longitudes of the planets. Usually it consisted of various disks, some fixed, some turning, to represent the deferents, equants, and epicycles of the Ptolemaic system. Kashi, who died in 1429, was an astronomer at the court of Ulugh Beg at Samarkand.

The present book reproduces the entire Persian manuscript in facsimile, with an English translation on the facing pages. There is also an extensive modern commentary, a brief biography of Kashi, and a bibliography.

The translation is hard reading. The anonymous Persian writes with an economy of phrase that occasionally results in an admirably direct and lucid explanation, as when he gives the reasons for the equation of time. But all too often the text is obscure, as when it treats of centers marked on the instrument without specifying which centers. He gives only one imperfect diagram in expounding a subject that calls for diagrams on every page.

E. S. Kennedy's modern commentary clears up much of the difficulty and supplies the missing diagrams. He assumes that the reader is already familiar with Ptolemaic astronomy and does not give much basic information on that subject, except when discussing the problem of planetary latitudes.

This equatorium has fewer movable parts than usual. A large metal disk rotates inside a ring which is divided into 360 degrees. Marked on the disk are the off-center deferent circles of the various heavenly bodies, while an alidade is



In his Fig. 1, the translator presents a redrawn diagram of Kashi's planetary equatorium, including a sketch at the lower right that shows how the parts fitted together. Courtesy Princeton University Press.

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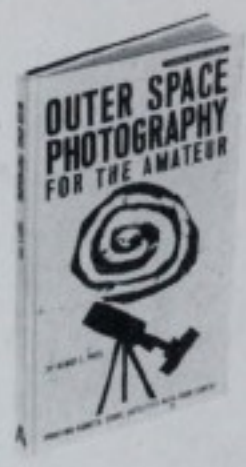

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pivoted at the center. The deferent and equant centers are also marked. A ruler and a page of tables provided in the manuscript complete the equipment. All the numerical data are generally close to but not identical with those that were used by Ptolemy.

All angles are indicated by the alidade on the outer ring and then moved out to the appropriate centers by the ruler, which is always placed parallel to the alidade. The radii of the epicycles are marked on the alidade. The operation is a little clumsy, and requires marks to be made on the instrument for each observation, but for longitudes it should work about as well as other equatoriums.

Kashi went on to make his instrument calculate planetary latitudes, and the commentary states that his is the only equatorium that would do this. Going even further, he discusses equatorium-obtained predictions of eclipses, both solar and lunar. However, in avoiding generalized predictions by saros in favor of detailed ones by latitude and longitude, he becomes involved in complicated techniques.

His directions require several points and lines to be drawn on the disk for each observation. Kashi's process is not so much the use of a mechanical instrument as it is the graphical solution of a series of triangles. Dr. Kennedy's commentary demonstrates that the geometry is usually, but not always, correct within the Ptolemaic framework. At times it is ingenious. At other times it is impractical, as when it involves measuring sine functions in a circle about the size of this letter "O."

The Planetary Equatorium is a careful, scholarly, and thorough piece of work. Unfortunately, there is no over-all summary of the accuracy of the results and the probable success or failure of Kashi's predictions. We would particularly like to know if he had any luck in predicting a solar eclipse. That is a complicated calculation requiring accurate data, and even though Kashi discusses such matters as eclipse limits and lunar parallax, one suspects that he had some disappointments.

The book includes all the information and tables for the reader to make and test his own equatorium. But Dr. Kennedy, who tells us his formal training was in mathematics, is clearly more adept than most of us in sexagesimal arithmetic and converting the Persian calendar to our modern one. We wonder if he has tried to predict an eclipse by Kashi's rules and how the answer agreed with T. Oppolzer. Instead, he leaves us with the remark that we should "retain mental reservations as to the practicality of the results" obtained by the methods described by Kashi.

The 15th-century Samarkand astronomer emerges from these pages as a somewhat pedantic person, who may have

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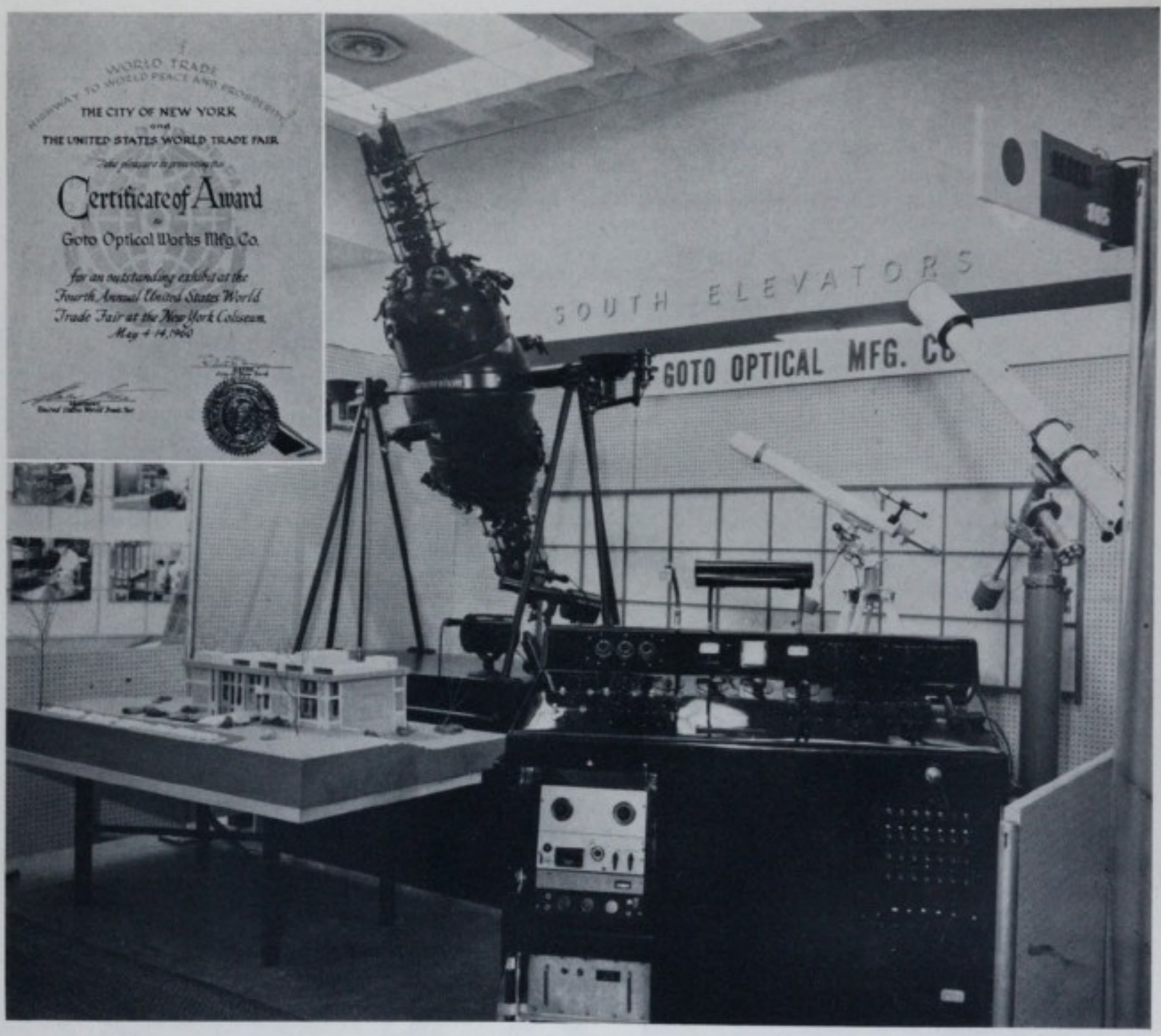
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THE FASCINATING WORLD OF ASTRONOMY

Robert S. Richardson. McGraw-Hill Book Co., Inc., New York, 1960. 274 pages. $5.95.

IF you were browsing through a bookstore for a good introduction to astronomy, you would notice this volume because of its title and attractive cover. After a quick examination of the chapter titles, photographs, and general layout, you would probably add it to your library. To prove this to myself, I laid *The Fascinating World of Astronomy* on my desk at work, as well as on a table in the living room at home. Everyone wanted to borrow it, or inquired where it could be purchased.

The author has obviously had long experience with the questions in astronomy so earnestly asked by the average layman, and he knows how to answer them. In fact, the question-and-answer motif is followed throughout the volume, which is neatly divided by subject matter into 17 chapters. Each of these is composed of from one to 19 queries, the replies being given in a single paragraph or several pages. No subject is exhausted to the point of boredom.

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Mathematics is avoided throughout, and the author has even managed to devote a chapter to "Telescopes and Measurements," in a comprehensive manner without benefit of formulas.

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sible answers. External galaxies are treated as greater aggregations of stars, and a final chapter is on constellations.

The text contains some clumsy if not incorrect grammar, and there are a few questionable statements that might badly confuse the beginner. The first three sentences of the text were obviously geared to attract the reader's full attention, but they are so constructed that this reviewer had to rearrange them to be sure he understood correctly. Dr. Richardson's frequent reference to the moon as a planet is confusing.

One might object to being told (on page 3), "If you visit an observatory in the morning, the place is deserted because the astronomers are all asleep." This can hardly be true in those larger institutions, such as Mount Wilson, Harvard, Yerkes, Allegheny, and the U. S. Naval Observatory, where astronomers far outnumber observing instruments and do most of their work during normal office hours.

Once we are over these rather minor hurdles, however, we find more than 200 pages of delightfully entertaining reading. For ready reference, the author has included an index of names and terms. This work can safely be recommended as one of the best of the new books inspired by the public's quest for astronomical knowledge.

CHARLES H. LeROY
Amateur Astronomers Association
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THE OCEAN OF AIR

David I. Blumenstock. Rutgers University Press, New Brunswick, N. J., 1959. 457 pages. $6.75.

UPON the skeletal elements of weather — sunlight, water, and air — meteorologist David Blumenstock has built an enjoyable anecdotal picture of climate and man. It is embellished with bits of information from fields as diverse as archaeology and nuclear warfare, resulting in a pleasing narrative of man's relations with particular climates. Indeed, the title is rather misleading, for it fails to indicate the author's continual attention to the people who live in the ocean of air.

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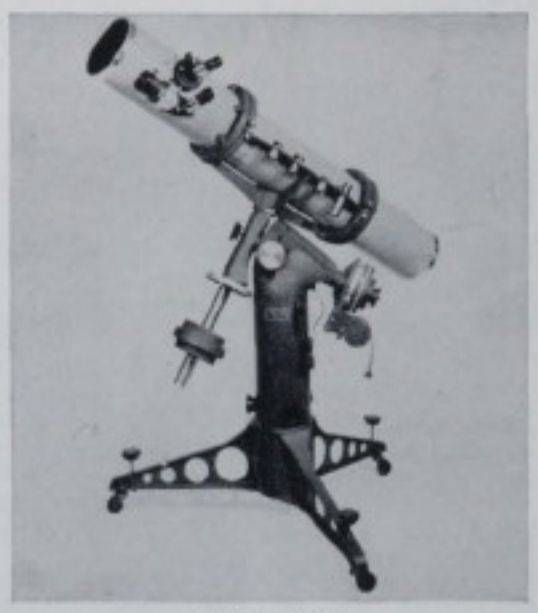

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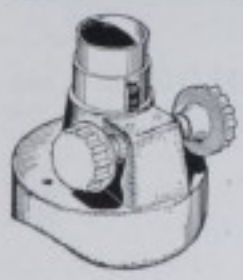

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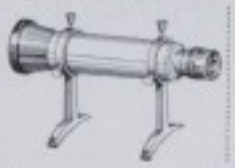

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such pressure differentials. A more easily understandable factor, temperature, is explained only briefly in connection with land-sea winds. Although the global wind systems — the trade winds, the polar easterlies, and the westerlies — are mentioned, the over-all structure of the world's temperature, wind, and pressure belts is not described. A few simple diagrams in the text would have clarified the global picture and given a background against which to view local weather systems.

Information on astronomy is limited to a 10-page qualitative discussion of meteors and meteorites, electromagnetic phenomena in the upper atmosphere, and cosmic rays.

Part Two, on the observation, prediction, and control of the ocean of air, continues the dramatic narrative of man's trials, successes, and failures in contending with the vagaries and dangers of the atmosphere. Samples of early weather lore introduce a description of weather instruments and forecasting techniques, including radar and artificial-satellite methods. The reader is put in the position of a forecaster presented with a welter of unselected meteorological data gathered from observing stations all over the world, but, unfortunately, he may be left bewildered by the flood of meteorological terms.

Dr. Blumenstock is not trying to make accomplished weathermen, and the book should not be read under that impression. Rather, he seeks to bring out the problems and uncertainties with which forecasters must daily cope in order to turn out any sort of reliable prediction.

The roles of weathermakers, rainmakers, and rain-preventers are humorously but carefully studied. The negative results of old practices like firing cannons every five hours to cause rain, and the inconsistent outcome of modern cloud seeding should make us beware of paying out large sums for such projects.

Dr. Blumenstock editorializes in the final part of his volume, which strays for a time from meteorology to the subject of war. Himself an army meteorologist during World War II, the author has taken the opportunity to state and repeat the dangers of a nuclear war and radioactive fall-out. There is much suspense in his tales of weather predicting for the launching of a major assault and calculating head and tail winds in long-range bombing missions.

Outright errors seems to have been avoided almost completely, although on page 165 the average lapse rate in the troposphere is given as 3.3 degrees Fahrenheit per 1,000 feet, whereas most meteorologists agree on a figure of 3.6 degrees.

The Ocean of Air contains much interesting historical and general information on weather and climates, and it certainly can be recommended for several hours of armchair enjoyment.

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Like the next three books listed below, Mr. Jaffe's volume forms part of the Science Study Series. Originated recently at Massachusetts Institute of Technology, this series is part of a new program to improve the teaching of science.

ACCELERATORS, *Robert R. Wilson* and *Raphael Littauer*, 1960, *Doubleday*. 196 pages. 95 cents, paper bound.

The development of cyclotrons and other particle accelerators and the reasons for their importance in modern research are explained in this nontechnical work by two Cornell University nuclear physicists.

THE UNIVERSE AT LARGE, *Hermann Bondi*, 1960, *Doubleday*. 154 pages. 95 cents, paper bound.

A leading British cosmologist gives a nontechnical account of some current views on the nature of the earth, the stars, and the universe of galaxies. This material originally appeared serially in *The Illustrated London News* in 1959-60.

THE WATERSHED, *Arthur Koestler*, 1960, *Doubleday*. 280 pages. 95 cents, paper bound.

This dramatic biography of Johannes Kepler is taken from novelist Arthur Koestler's recent book, *The Sleepwalkers*. It contains an extended factual account of Kepler's discoveries and writings.

PRINCIPLES OF STELLAR DYNAMICS, *S. Chandrasekhar*, 1960, *Dover*. 313 pages. $2.25, paper bound.

The motion of stars in the galaxy, in clusters, and in other stellar systems, is the subject of this technical monograph, first published in 1942. Included in the reprint are two further papers of 1943 by the Yerkes Observatory astronomer, on dynamical friction and on new methods in stellar dynamics.

THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC FOR THE YEAR 1962, *Nautical Almanac Office*, U. S. Naval Observatory, 1960, *U. S. Government Printing Office*, Washington 25, D. C. 514 pages. $4.00.

This standard reference work for astronomers is identical in plan with the preceding volume. Precise ephemerides for the sun, moon, planets, and the first four asteroids, and much other valuable information make this work indispensable to the serious observer. Conversion tables and full explanations of the contents facilitate use. Of wide interest is the day-by-day listing of astronomical phenomena.

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Assembled — ready to use! See Saturn's rings, the planet Mars, huge craters on the moon, star clusters, moons of Jupiter, double stars, nebulae, and galaxies! Equatorial-type mounting with locks on both axes. Aluminized and over-coated 3"-diameter f/10 primary mirror, ventilated cell. Telescope comes equipped with a 60x eyepiece and a mounted Barlow lens, giving you 60 to 180 power. A finder telescope, always so essential, included. Sturdy, hardwood, portable tripod.

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New Vibration-Free Metal Pedestal Mount

With this scope you can see everything described above, but with greater power. Also, it will split closer double stars. Mirror has twice the light-gathering power. Rack-and-pinion focusing, real equatorial mounting — only one motion needed to follow the stars! Aluminum tube. 6-power finder telescope. 2 standard-size eyepieces and mounted Barlow lens give you powers of 40x, 90x, 120x, and 255x. Low-cost accessory eyepiece available for higher powers. **FREE** with Scope: Valuable **STAR CHART** plus 272-page **"HANDBOOK OF THE HEAVENS"** plus the book **"HOW TO USE YOUR TELESCOPE."** Shipping wt. 25 lbs.

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Same telescope as described above but equipped with Electric Clock Drive.

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The orthoscopic eyepiece is one of the most important and best corrected eyepieces for astronomical work. These are of a four-element design, with coated lenses, and are standard 1¼" outer diameter, precision made of chrome-plated brass and aluminum.

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Stock #70,343-Y.....**$10.00 ppd.**

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White metal screen is easily attached to holder and placed behind eyepiece. Point scope at sun, move screen to focus . . . and you can see sunspots!

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Includes brackets, 28¾" rod, projection screen, screws, and directions. Aluminum; brackets black crinkle painted.

Stock #70,162-Y.....**$9.95 ppd.**

PRISM STAR DIAGONAL

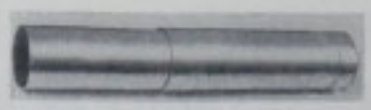
For comfortable viewing of the stars near the zenith or high overhead with refracting telescopes using standard-size (1¼" O.D.) eyepieces, or you can make an adapter for substandard refractors. Contains an excellent high-quality aluminized right-angle prism. The tubes are satin chrome-plated brass. Body is black wrinkle cast aluminum. Optical path of the system is about 3½".

Stock #70,077-Y.....**$12.00 ppd.**

AMICI-PRISM STAR DIAGONAL

Same as above except contains Amici roof prism instead of usual right-angle prism. Thus your image is correct as to top-bottom, making it excellent for terrestrial viewing.

Stock #50,247-Y.....**$12.00 ppd.**



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Stock #30,390-Y..Tie Clasp.....**$2.75 ppd.**

WAR-SURPLUS TELESCOPE EYEPIECE

Mounted Kellner eyepiece, type 3. Two achromats, focal length 28 mm., eye relief 22 mm. An extension added. O.D. 1¼", standard for most types of telescopes. Gov't. cost $26.50.

Stock #5223-Y.....**$7.95 ppd.**

6X FINDER TELESCOPE

Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 2 holders each with 3 centering screws for aligning with main telescope. 20-mm.-diameter objective. Weighs less than ½ pound.

Stock #50,121-Y.....**$8.00 ppd.**

STANDARD 1¼" EYEPIECE HOLDER

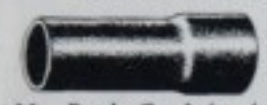
Here is an economical plastic slide-focus eyepiece holder for 1¼" O.D. eyepieces. Unit includes 3"-long chrome-plated tube into which your eyepiece fits for focusing. Diagonal holder in illustration is extra and is not included.

Stock #60,067-Y.....**$2.50 ppd.**

Stock #60,049-Y
Diagonal holder.....**$1.00 ppd.**

EDMUND SCIENTIFIC CO.

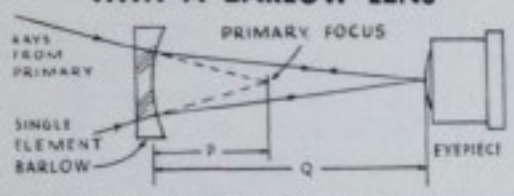
THE ORIGINAL GOODWIN RESOLVING POWER BARLOW



For many years, this achromatic coated Barlow lens has been the pride and joy of serious astronomers. Due to the death of the designer, Mr. Frank Goodwin, it has not been available for the past two years. NOW, we can offer these lenses, in exact accordance with the original specifications. Remember, this Barlow is achromatic, coated, mounted in a blackened tube, and as optically perfect as only precision craftsmen can make it. Complete with instructions, in a 4"-long adapter tube for standard 1¼" eyepieces.

Stock #60,122-Y.....**$23.50 ppd.**

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.

Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing, with special spacer rings that enable you easily to vary the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼" I.D. tubing, then slide your 1¼" O.D. eyepieces into our chrome-plated tubing. Barlow lens is nonachromatic.

Stock #30,200-Y...Mounted Barlow lens....**$8.00 ppd.**

UNMOUNTED 3X BARLOW LENS

These lenses are made for telescopes that have smaller-diameter eyepieces than the standard 1¼" size. Mount one between the eyepiece and objective, and triple your power. Instructions included. Single-element lens, focal length −1-5/16", unmounted.

Stock #30,185-Y....0.932" diam.....**$3.50 ppd.**
Stock #30,328-Y....0.912" diam.....**$2.50 ppd.**

3X ADJUSTABLE-DIAMETER BARLOW LENS

For telescopes with eyepieces smaller than the standard 1¼" outer-diameter size. Prongs on mount can be opened or closed to fit tubes from 13/16" to 1" inner diameter. Directions for using included.

Stock #30,339-Y.....**$5.00 ppd.**

MORE POWER FROM YOUR JAPANESE TELESCOPE

Mounted Barlow for Japanese Telescopes

By inserting this single-element lens in the eyepiece end of your Japanese telescope, and putting your regular eyepiece in the end of the Barlow tube, you can increase your telescope's power up to three times. Thus, instead of 60x, you will get 120x or 180x. Barlow is mounted in two pieces of telescoping brass tubing each 4" long, satin chrome plated on the outside. Inner diameter of large tube and outer diameter of small tube are 0.965", the standard size for most Japanese telescopes. Measure yours before ordering. 0.965" is approximately 31/32" or 24.5 mm.

Stock #30,370-Y.....**$6.00 ppd.**

SPECIAL!
VARIABLE 10- TO 20-POWER U. S. ARMY OBSERVATION TELESCOPE

This is the most versatile and complete government - surplus telescope unit we have ever offered you. USES: spotting scope, surveying, balloon and satellite tracking, all general observation. *THE TELESCOPE:* Elbow-type, 10 to 20 power continuously variable. Field of view 6° 9' to 3° 5'. 2¼" objective lens. Focusing eyepiece. *THE MOUNTING:* This is really something! Has completely enclosed 8"-diam. circle scale reading directly to 1/10 mil or approx. 20 seconds. (6400 mils equal 360°.) Clutch release allows rapid rotation. Rotates 90° horizontal to vertical with direct reading to 1 mil. Has crossed levels, precision adjustment, and many other exciting features. *THE TRIPOD:* Made of solid oak with brass fittings. Has cast brass head with four leveling screws. Legs adjustable from 30" to 52" excluding mount height. Extremely sturdy and rigidly cross braced. Instruments used but in good condition. Shipping wt. approx. 100 lbs.

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CLOCK-DRIVEN EQUATORIAL MOUNT ON PEDESTAL BASE IDEAL FOR YOUR 6" OR 8" REFLECTOR

Accurate electric clock drive and heavy-duty mounting. Operates on household current. Follows stars smoothly. Pedestal is 24" high. Polar-axis shaft diameter 1".

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Same mount and clock drive on 32" hardwood tripod.

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Same mount on metal pedestal, no clock drive.

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Same mount on tripod, no clock drive.

Stock #85,023-Y.....**$39.50** f.o.b. Barrington, N. J.

STARS THAT GLOW IN THE DARK

Transform your den or bedroom into a realistic night sky. Schools, too, can set up authentic sky scenes showing constellations, planets in a dark room for daytime lectures or explanations of earth and space science. Equally attractive as a means of making your children's room a fairyland, where their canopy of stars will make them welcome rather than fight "lights out." Set consists of 125 luminous star decals made of a safe, nonradioactive phosphor. Stars glow after exposure to strong light.

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Mounted Ramsden Eyepieces

Standard 1¼" Diameter

Our economy model, standard-size (1¼" O.D.) eyepiece. We mounted two excellent quality plano-convex lenses in black anodized aluminum barrels instead of chrome-plated brass to save you money. The clear image you get with these will surprise you. Directions for using short focal length eyepieces are included with both the ¼" and ½" models.

Stock #30,204-Y.....¼" focal length.....**$4.75 ppd.**
Stock #30,203-Y.....½" focal length.....**$4.50 ppd.**

STAR AND SPACE MAPS

Three giant maps: 1. THE SOLAR SYSTEM, 50" x 38", showing planet statistics; detailed moon map; 12 telephoto pictures of moon, sun, planets. 2. WORLD STAR CHART, 50" x 38"; locates stars for any time of year, any position on earth. 3. MAP OF THE SOLAR SYSTEM, 35" x 48"; shows planets, zodiac, and so on.

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MAP OF THE MOON

Edmund Scientific Co. strongly recommends this moon map. 35" x 46" photographic reproduction of the whole moon — a very helpful aid. It is in black and white and has all named lunar formations clearly marked. In addition, it gives a complete index to their locations and much valuable lunar information.

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GIANT ERFLE EYEPIECE 1½" F.L.

War-Surplus Bargain — Gov't. Cost Approx. $100

Large telescopes should have one of these for low-power viewing. Apparent field of view 65°. Also use with the 24"-focal-length Aerial Camera lens to make a 16-power wide-field telescope or a 27-power scope with one of the 40"-focal-length Aerial Camera lenses. Low-reflection-coated, 5-element lens system. Field lens of Eastman Kodak's rare-earth glass for better aberration correction. Has diopter scale. Smooth focusing ⅜" movement. Outside diameter of attaching threads, 3" — 32 threads per inch. Clear aperture of eye lens 2", field lens 1-25/32". Weight 3½ lbs.

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This adapter lets you use our Giant Erfle with any telescope having a standard 1¼"-diam. eyepiece holder.

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MAKE 8X ASTRONOMICAL SCOPE with Low-Cost Beginner's Kit!

Now anyone from Cub Scout or Brownie age on up can make his own 8-power astronomical telescope in one evening, without tools or machinery. Kit includes objective lens, field lens, eye lens, glare stops, kraftboard tubes, cadmium-plated metal ferrules, and other parts to build an 18"-long, 1¼"-diameter telescope of 8 power.

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PYREX-brand glass diagonals, 1/8-wave accuracy.

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★ DETAILED, ILLUSTRATED INSTRUCTIONS, "Mirror Making in the Kitchen"

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6-inch kit ..... **$15.00 ppd.**
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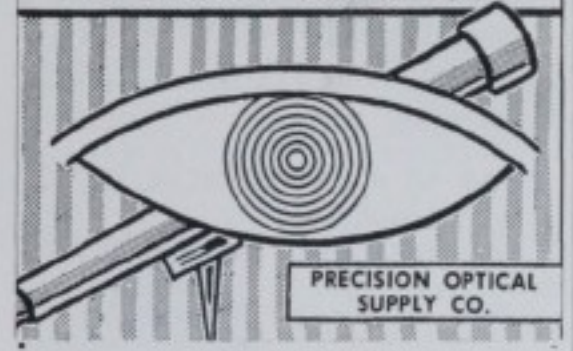

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An Inexpensive but Accurate Sidereal Drive

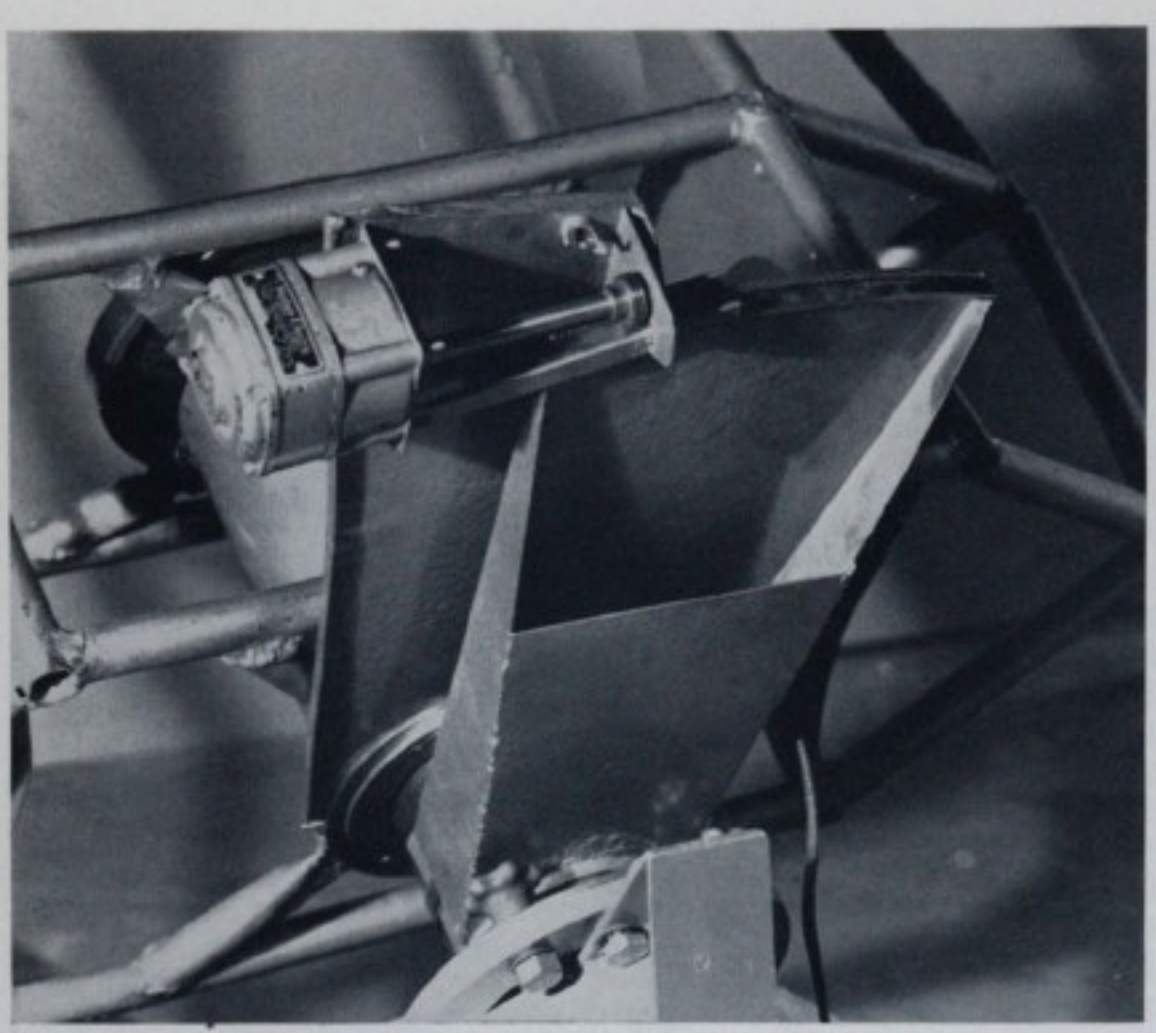
AFTER BUILDING and mounting my 12½-inch Newtonian reflector, I decided that a good sidereal drive was needed if the instrument was to be fully utilized, especially at high powers. To fit my fork-type mounting, an expensive special-order worm and gear and a driving-clock gear train would normally be required. Instead, I made a tangent arm and two-hour sector to obtain a drive that is simple, precise, and of low cost.

Before deciding on the type of drive for an amateur instrument, however, one should consider several factors: How long will the telescope usually be pointed at a single celestial object or sky field? Fifteen minutes? Three hours? How accurate must the drive be, and which is superior for the funds available, a worm-gear combination or a sector and tangent arm? Is a gear train necessary?

Concerning the first question, an amateur's regular observation of a star, nebula, or planet seldom exceeds 15 minutes or half an hour, and few of us make photographs longer than two or three hours. Even for a three-hour exposure, seven-eighths of the teeth in a polar-axis gear are needless, except for the convenience of not having to reset the worm at the end of this interval. Before the advent of long-exposure photography at the turn of the century, many instruments at professional observatories were equipped with tangent-arm drives instead of worm gears.

Many factors affect the accuracy of a worm-gear drive. Most important are the care with which the worm and gear are made and how closely they match each other, so the teeth fit perfectly without free play and backlash. The smaller the gear, the greater the precision required in manufacture. On the other hand, it is very difficult to make a large gear with uniformly matched teeth around its entire circumference, so such a gear is prohibitively expensive for amateurs.

Glenn L. Wilson stands on the observing ladder of his 12½-inch reflector. At the base of the polar axle, center foreground, is the worm-driven tangent arm and 30-degree sector. At the top of the tube, spider and eyepiece revolve as a unit. Photographs with this article are by Glenn L. and James Wilson.



The double-plate sector gear extends from bottom center toward upper right in this view of the tangent-arm drive. The 1-r.p.m. motor is at the upper left.

As further simplification, I decided that an elaborate driving clock was unnecessary. In a gear train, inaccuracies accumulate from imperfect gears and slightly loose bearings. I simply put the worm directly on the output shaft of a synchronous motor (2- to 6-watt will do) giving one revolution per minute. The worm engages a sector having 120 teeth in an angle of about 30 degrees, and 120 turns of the motor shaft drive the telescope for about two hours.

But segments of large gears are quite expensive too, so a substitute had to be found. This is a $\frac{1}{8}$" strip of brass rack (Boston Gear No. Y48), gently bent over a form of the correct radius. To engage the teeth thus obtained, I ordered a Boston worm No. LSH, and found the two worked well together. The $\frac{1}{8}$" width of the rack may seem rather small, but it is so far from the polar axis and is driven so slowly that greater strength is not needed. Boston Gear Works has distributors in a hundred cities from coast to coast.

The spacing of the teeth of the rack determined the radius to make the sector. If a telescope is to be used for photographic as well as visual observing, I believe the best single speed is one that supposes there are 1,436.5 minutes (instead of 1,436.07) in a sidereal day. This makes the telescope run about one second per hour slower than the true sidereal rate and compensates partly for the effect of atmospheric refraction. If a full gear were used with a 1-r.p.m. motor, its circumference would contain 1,436 teeth to drive close to the sidereal rate.

The lead, or distance between the teeth of the rack, is 0.0654", so if 1436.5 of these teeth were formed into a circle its

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★ 2 mirror blanks of PYREX-brand glass
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8"	1⅜"	$18.75
10"	1¾"	$33.65
12½"	2⅛"	$59.95

ADD POSTAGE: 1st, 2nd, and 3rd postal zones from Detroit, add 10%; 4th, 5th, and 6th, add 15%; 7th and 8th, add 20%; or we will ship postage collect.

Send for free catalog of supplies.

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ALUMINIZING
ALUMINUM OVERCOATED
CHROMIUM ALLOY

★ ★ BERAL COATINGS ★ ★

The ideal coating for front-surface **precision** mirrors for these reasons:

1. Beral has HIGH reflectivity.
2. Beral is HARD; does not sleek easily.
3. Beral can be cleaned easily — no porous OVERCOATING of quartz.
4. Beral is NOT a Chromium alloy, so can be removed easily.

Prices for Beral coating telescope mirrors: 4", $3.50; 6", $5.00; 8", $6.50; 10", $8.50; 12½", $12.50. Prices for sizes up to 37" diameter on request. Add Postage — Insurance for return mail.

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8038 MONTICELLO AVE. SKOKIE, ILL.

the 4¼" De Luxe VERNONscope

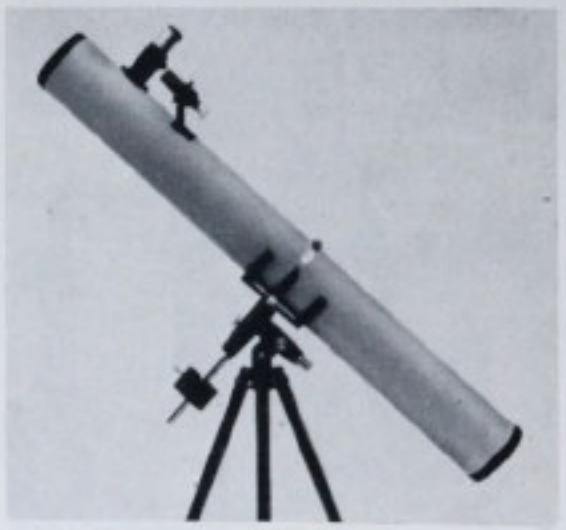
Now you can own and enjoy the performance and workmanship of one of the most unusual reflecting telescopes available at only **$79.50**

With These Ultimate Features:

★ 4¼" PYREX-brand glass parabolic mirror, f/10, ground and polished to better than ⅛ wave, aluminized and overcoated with quartz for maximum optical protection, guaranteed to perform to Dawes' astronomical limit of resolution. Highly accurate elliptical diagonal is included.
★ NEW, rugged PAR Jr. Equatorial Mount, designed to give utmost rigidity at the points of greatest stress (note tapered aluminum housings). Includes latitude adjustment, large knurled locking screws and close-tolerance machined bearings with ⅜" chrome-plated precision-ground steel shafting. Base of mount is fully rotatable for altazimuth viewing and can be quickly disassembled from the tripod. Steel legs fold for easy portability. Mount has black primer and 3-dimensional space-blue marbleized finish.
★ Seamless aluminum tube, blackened inside, with 3-D space-blue finish.
★ New achromatic-type 4x finder with crosshairs and adjustable mounting bracket.
★ Smooth, 1¼" precision helical focusing unit permits micrometer accuracy to give sharpest images possible.
★ Machined aluminum end caps and adjustable mirror mounting.
★ Covers for all optical components.
★ 44-page telescope operation manual included.

Instrument as described above, with 2x Barlow and choice of 25-mm., 18-mm., or 9-mm. Kellner ocular **$79.50**
— with your choice of any two Brandon Orthoscopic oculars **$97.50**
— without any eyepieces **$69.50**

Telescopes are completely assembled, thoroughly tested, and correctly aligned before leaving the factory. Orders received by December 15th can be delivered in time for Christmas.



4¼" VERNONscope ... $79.50
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We unconditionally guarantee the 4¼" VERNONscope to be exactly as described and illustrated, and to surpass even your greatest expectations, or return it within one month and your money will be immediately refunded. VERNONscope & Co. is the sole manufacturer of the 100%-American-made 4¼" VERNONscope, selling to our customers direct from the factory. Send your order today for immediate delivery.

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Easy Low-Cost Way To Enjoy Thrills Of Astrophotography

Convert your present 35-mm. Camera with this new Adapter

Developed by Criterion especially for single-reflex 35-mm. cameras with interchangeable lens. Simply remove present lens mount and add this precision-made achromatic lens that adapts camera to eyepiece of any telescope — refractor or reflector. When ordering, *be sure to specify make of your camera.*

For 35-mm. cameras with SCREW-TYPE lens mount
Cat. #CPA-36 for 1¼" eyepiece holders..**$19.00**
Cat. #CPA-37 for 4" standard Dynascopes **$17.50**

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New!

Dyn-o-Astro 35-mm. Camera

at less than regular price of camera alone!

No need to be an expert photographer to take exciting astrophotos with this *single-reflex*-type, precision-made 35-mm. camera. No complicated settings. No plates or filmholders to load and unload. No worries about missing target. Large focusing screen shows you *exactly* the viewing field up to moment of shooting.

- — No accidental double exposures. Winding knob automatically advances film, positions mirror, winds shutter, counts exposures.
- — Dual-speed setting knob controls both fast and slow shutter speeds. Color coding makes mistakes impossible.
- — Integrated magnifier for critical focusing even on dim objects.

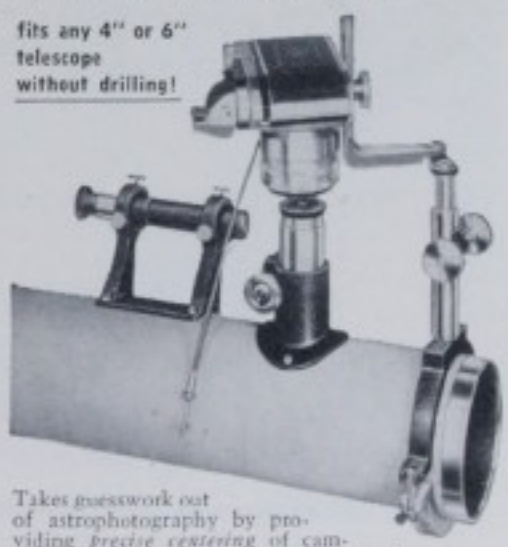
Takes time exposures and also has speeds up to 1/500 second. Guaranteed for 2 years. Complete, ready for use.

Model CP-35 fits 1¼" eyepiece holder **$89.00 postpaid**

Model CP-36 fits all standard 4" Dynascopes **$85.00 postpaid**

Dyn-o-Swing Camera Support

fits any 4" or 6" telescope without drilling!



Takes guesswork out of astrophotography by providing *precise centering* of camera over eyepiece. Smooth rack-and-pinion adjustment. Easily attached or detached from tube, with rigid clamp for maximum stability. Special arm lets you swing camera away from eyepiece for visual observation, with instant return for photographing. Can be used with almost any camera. Postpaid.

Cat. #CS-4 to fit all 4" Dynascopes..... **$17.50**
Cat. #CS-47 to fit all 4¼" O.D. tubes..**$18.95**
Cat. #CS-67 to fit custom 6" Dynascope and 7¼" O.D. tubes..... **$19.95**

Catalog F, describing other accessories and parts, cheerfully sent on request. Satisfaction guaranteed, or money refunded. All items sent postpaid. We pay all postage costs. No shipping, crating, or packing charges. Send check, cash, or money order for immediate delivery.

Criterion Achromatic Barlow

This precision Barlow features an achromatic, coated lens, perfectly centered and corrected for finer resolution than you've ever experienced. Intensively tested and proven superior, achromatic lens is mounted in a precision cell. Gives 2.4x magnification. Definition is clear and sharp, hard to the very edge.

Model CP-4 fits standard 1¼" eyepieces..**$17.50**
Model CP-2 fits small 0.946" eyepieces...**$15.50**

Paraboloidal Mirrors

Aluminized, zircon-quartz overlaid. Guaranteed unconditionally to perform to the limits of resolution. Hand-corrected to exacting specifications, and guaranteed superior.

4" f/8	**$42.00**
4" f/10	**31.00**
6" f/8	**55.00**
6" f/9	**50.00**
8" f/8	**89.00**
10" f/7	**179.00**
12½" f/7	**299.00**

All mirrors made of **PYREX**-brand glass

A tolerance of 5% in focal length is customary. A deposit of ⅓ is required with orders for 8" to 12½" mirrors.

Reflecting Telescope Mirror Mounts

Mounting the mirror to your scope correctly is most important. Criterion mounts are especially well designed, and are made of cast aluminum with brass mounting and adjustment screws. One section fits tube, other section holds mirror. Alignment accomplished by three spring-loaded knurled adjusting nuts. Outer cell designed to fit into or over your tube. Sufficient space left between the two cells. All drilled and tapped. Complete with holding clamps, springs, nuts, etc. Ready for use. Will prevent vibration and hold alignment once set. Will hold mirror without distortion of surface figure.

3"	**$3.00**	6"	**$6.50**
4"	**3.50**	8"	**12.50**
5"	**4.00**	10"	**19.50**

Complete Eyepieces

Finest quality. They are precision machined, mounted in standard 1¼" outside diameter barrels. Can be taken apart for cleaning. Designed to give sharp flat field clear to edge.

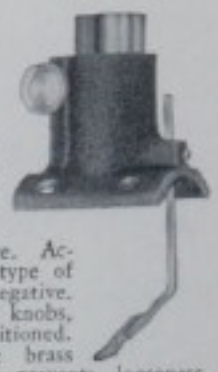
Huygens 18-mm. f.l. (¾")	**$ 7.50**
Kellner 9-mm. f.l. (⅜")	**7.90**
Kellner 7-mm. f.l. (9/32")	**8.50**
Kellner 12.7-mm. f.l. (½")	**9.50**
Kellner 18-mm. f.l. (¾")	**9.50**
Kellner 30-mm. f.l. (1-3/16")	**12.50**
Orthoscopic 6-mm. f.l. (¼")	**12.50**
Orthoscopic 4-mm. f.l. (5/32")	**14.50**

Revolving Turret

The Criterion Revolving Turret holds three eyepieces so that, as desired, the power of the telescope can be changed by merely turning the turret to a different ocular. Click stop insures positive and accurate positioning of each eyepiece. Turret holds eyepieces of standard 1¼" outside diameter. Fits into the holder of any refractor or reflector telescope that uses 1¼" eyepieces. Requires no alteration or adjustment and can be attached as easily as putting eyepiece into scope. Made of brass and aluminum with polished chrome-plated barrels.

Cat. #SKT-350..... **$14.50**

Rack-and-Pinion Eyepiece Mount



The most mechanically perfect focusing is by rack and pinion. This mount takes standard 1¼" eyepieces. Full 3½" of travel — more than ever before. Accommodates almost any type of eyepiece — positive and negative. Two knurled focusing knobs, variably tensioned and positioned. Solid cast-metal sliding brass tube — close tolerance prevents looseness. Mount aligns itself to any type tube. Four mounting holes, nuts and bolts included. Eye mount has square-rod-type diagonal holder which prevents loose alignment and vibration. Rod tempered to minimize temperature changes. Adjustable for 3" to 8" scopes, also 12" scopes if so specified at no extra cost. Order one or more of the complete eyepieces described below at the same time you send for this rack-and-pinion device, which accommodates any of our eyepieces perfectly.

Cat. #SU-38..... **$7.95 postpaid**

New Model Eyepiece Mount

Same features as above but has wider base that is contoured to match the curve of a 7" to 8" diameter tube. Makes professional appearance. Furnished without Diagonal Rod #SU-9R. **$9.95**

Diagonal Rod — Cat. #SU-9R..... **$1.00**

Achromatic Finder Scopes

Two models: 6x, 30-mm., and 10x, 42-mm. Coated achromatic air-spaced objective, crosshairs, built-in duraluminum tube finished in white enamel, dewcap. Sliding focus adjustment. Can also be used as excellent hand telescopes for wide-field views of the sky. Fit Mount Bracket #SF-610.

6 x 30 Achromatic Finder	**$12.50**
10 x 42 Achromatic Finder	**$18.00**
Mount Bracket #SF-610	**$9.95**

Wide-Angle Erfle Eyepiece

Our 16.3-mm. Erfle wide-angle eyepiece has a 75° field. Astonishing wide-angle views. Coated. Highest precision and specifically designed for telescopic use. Chrome barrel. Guaranteed to be superior in every respect.

Cat. #SE-63 — 1¼" O.D.	**$18.50**
Cat. #SE-62 — 0.946" O.D.	**$16.50**

Four-Vane Diagonal Holders

Criterion 4-vane diagonal mountings are fully adjustable, will hold elliptical diagonals in perfect alignment. Made of brass, chemically blackened. Precision adjusting screws center flat and vary its angle so that primary and secondary mirrors can be set in perfect alignment. Thin vanes with special adjustable studs.

Cat. #	Minor-Axis Size	For Tubes	Price
S-51	1.25"	6½" to 7½"	**$10.00**
S-52	1.30"	6½" to 7½"	**10.00**
S-53	1.50"	8½" to 9½"	**10.00**
S-54	1.75"	9½" to 10½"	**12.50**
S-55	2.00"	11" to 11½"	**14.95**
S-56	2.50"	Specify tube I.D.	**19.95**

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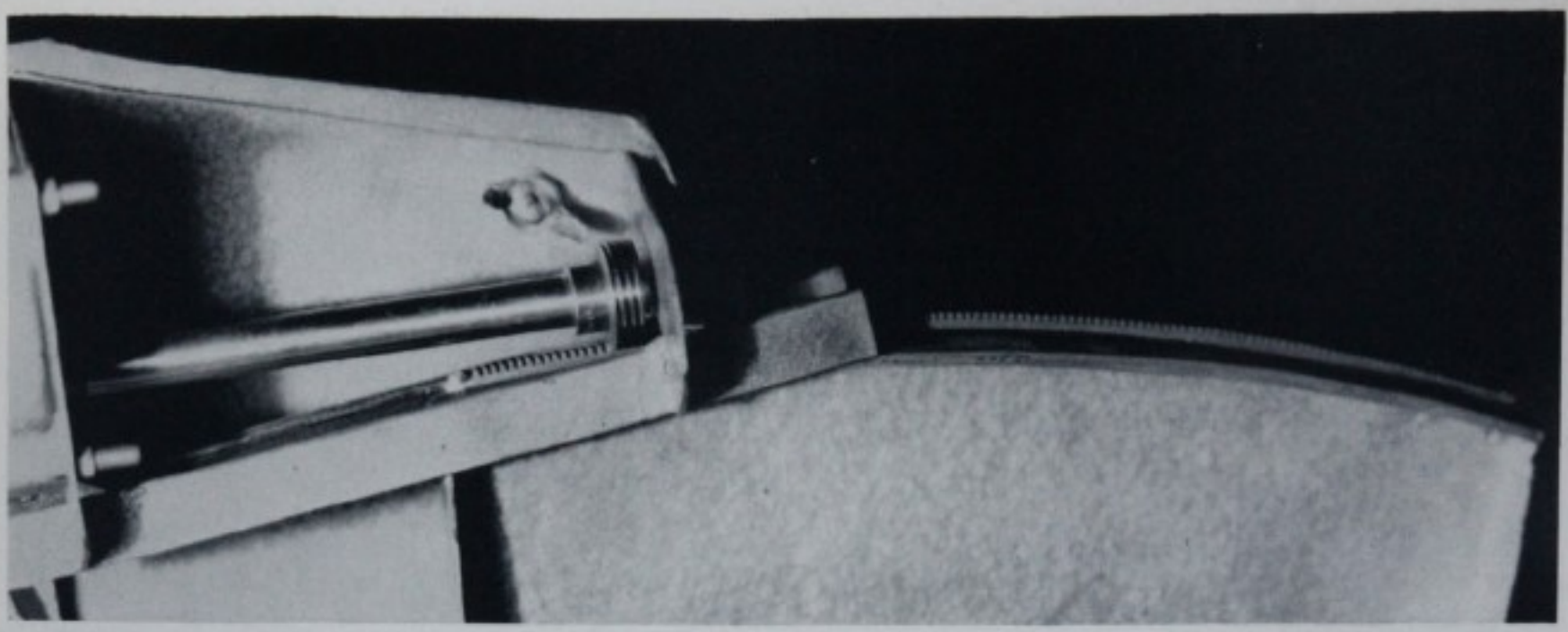

In this close-up view, the worm's position on the rack shows that about 1¼ hours have elapsed since the drive was set. Loosening the wing nut to the left of the worm allows the latter to be moved back to the beginning end of the rack.

circumference would be 93.9471″ at the pitch line, which is the effective depth in the teeth that is being driven by the worm. Dividing this result by π (3.1416) gives the pitch diameter of the gear, 29.904″. This is a very convenient result, for the radius of the sector is close to 15 inches, large enough for precise driving, yet not too large to construct easily.

The specified distance from the pitch line to the back of a Y48 rack is 0.104″, reducing the pitch diameter by 0.208″ to 29.696″. But when the rack is bent to match the segment arc, the teeth open out slightly. I calculated this effect on the basis that the center line of flexure would fall about halfway between the bottoms of the teeth and the back of the rack. The loss around the entire circumference came out 0.208″, or 0.066″ in the diameter. To compensate, half of this value should be added to the radius, giving a final figure of 14.881″, which is what I worked for in constructing the sector.

Sheet steel of 18 gauge was cut, formed, and welded to make the sector and tangent arm. The outer edge of the sector arc was left with 0.01″ for finishing smooth with a file. To complete the surface for the rack, the assembly was mounted on the stationary polar axle and a dial indicator attached, by means of a

SATELLITE 3-INCH

$29.95

Completely assembled 3-inch reflector * All-metal construction with seamless aluminum tube * Standard 1¼-inch rack-and-pinion focusing eyepiece mount * Corrected optics for fine definition * Collapsible self-locking metal tripod * Peep-sight finder * 60-power eyepiece * (120-power eyepiece available, $4.00) * With altazimuth mounting, $29.95 * With equatorial mounting, $39.95 * f.o.b. Pottstown, Pa.

BOOKLET, "Instructions To Establish Your Telescope and To Set and Use Your Setting Circles." 21 pages. **$1.00 ppd.**

SPACE K-4 DELUXE

$79.95 KIT

$98.50 ASSEMBLED

OUR SPACE K-4 DELUXE . . . nationally recognized by astronomers and schools for its outstanding performance. Purchased by schools under NDEA for teaching astro-sciences, the SPACE K-4 DELUXE is available completely assembled for $98.50, or as a kit with assembled optics for $79.95, f.o.b. Pottstown, Pa. Prices include 3 eyepieces: 50x, 100x, and 200x, standard 1¼″; 6 x 25 achromatic finder; adjustable equatorial mount; pedestal; and collapsible legs. This 4¼″ reflector is also available with clock drive and setting circles.

All prices subject to change.
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PLANETARIUM SHADE

Attractively styled lamp shade provides the finishing touch for anyone interested in astronomy and space science. Constructed of durable translucent stock and printed in color. Stars appear white with outline of 37 constellations on deep blue background. Constellations of spring, summer, fall, and winter accurately scaled and identified by name, with Milky Way, zodiac, and equator outlined. Size, 12″ diameter, 8½″ high. Supplied with clip or washer-type mount (specify which when ordering). Ideal gift. Practical and educational. **$5.98 ppd.**

FAVORITE CONSTELLATIONS OF THE NORTHERN HEMISPHERE

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A photographic atlas of the sky from declination −30° to the North Pole. This set of **33 slides** on 35-mm. film is made up of actual **unretouched photographs** requiring almost three years to obtain using special equipment. Set includes 39 slides — one title, five star maps, and 33 constellations. Each slide mounted and identified. Suitable for projection with any 35-mm. equipment on screen and ceiling for lectures and teaching. This is the finest set of slides we have ever seen; each constellation is sharp and clear with excellent contrast. Instructions included. **$16.00 ppd.**

Inquiries from schools, clubs, dealers, and planetariums invited.

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TRIGARTH TURRET
and
Eyepiece Attachment with Rack and Pinion

Just turn the Trigarth Turret and easily improve the performance of your telescope. It holds three eyepieces of standard 1¼" O.D. The Trigarth Turret sells for **$15.95 postpaid.**

Also priced at **$15.95 postpaid,** the Eyepiece Attachment with Rack and Pinion takes standard 1¼" O.D. eyepieces. The rack and pinion is machined from solid aluminum castings, precisely fitted for smooth performance. Main tube, 1¾" long; sliding tube adds 2"; total movement, 3¾". Choice of gray or black crinkle finish.

Both Turret and Eyepiece Attachment, **$31.90.**

Satisfaction Guaranteed.

Write for Free Catalog, Instructions, 10¢.

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SPECIAL OPTICS — TO YOUR DESIGN

Prototypes or small quantities of:

★ Mirrors of all kinds
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— also special mechanical-optical and electro-optical assemblies.

We will quote on your requirements.

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UNIVERSAL RACK-AND-PINION FOCUSERS

For reflectors or refractors.

Take standard 1¼"-diameter eyepieces. Specially designed base fits any tube 5" or more in diameter. Carefully machined aluminum and brass construction permits critical setting. Slotted extension tube holds eyepiece firmly and gives sufficient working distance for Barlows. $9.95 postpaid

MIRROR CELLS

Solid cast aluminum, fully adjustable, painted, complete and ready to use. Shipped postpaid.

6" mirror cell for	7"	or larger tube	.....	$6.75
8"	"	9"	"	..... 8.95
10"	"	11¾"	"	..... 15.95
12½"	"	14½"	"	..... 20.95

MIRROR-MAKING KITS

with PYREX-brand mirror blanks and new velvet-finishing tools.

4¼"	diameter . . .	$5.70	postpaid
6"	" . . .	9.50	postpaid
8"	" . . .	12.25	shipped collect
10"	" . . .	21.75	shipped collect
12½"	" . . .	41.25	shipped collect

Kits include five abrasives, with our special superfine finishing abrasive for superior fine grind, selected pitch, cerium oxide, PYREX-brand mirror blanks, and velvet-finishing tool (heat resistant, approximate hardness of mirror blank). C.O.D.'s accepted.

Used telescopes, binoculars, microscopes, and optics bought, sold, or exchanged.

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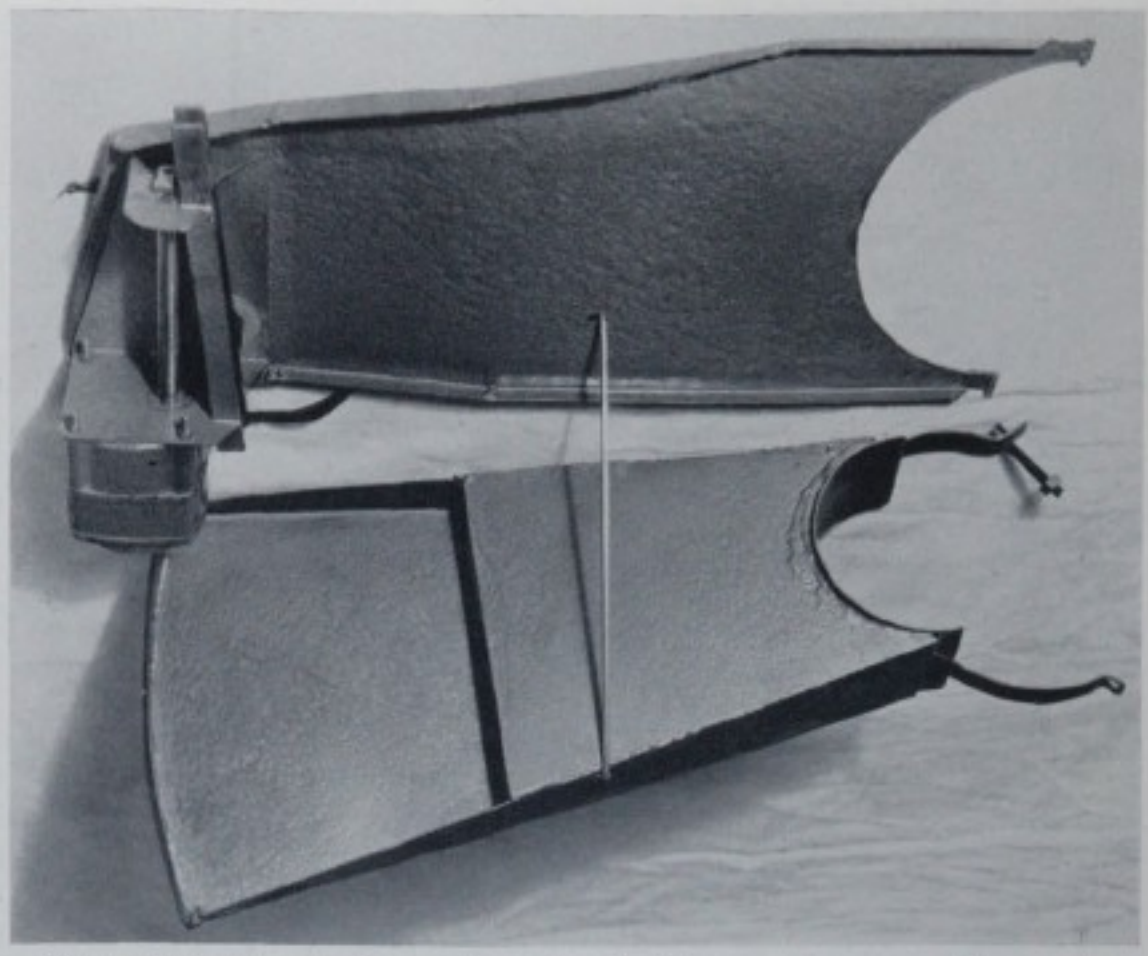

These parts make up the complete sidereal drive: motor, worm, and tangent-arm plate at top, sector gear at bottom. The 123-tooth rack is seen in the center, before it was bent to the radius of the sector.

magnetic base, to the rotating fork of the telescope. With this arrangement, I could control the radius of the sector to 0.001". Then teeth were filed off each end of the rack (leaving 123 to engage the worm) and it was secured with a 2-56 machine screw at each end.

I cut some more steel sheet for a plate to mount the motor, shaft, worm, and guides that fit on each side of the rack. These parts are mounted on the plate as a unit, and this is fastened to the tangent-arm plate by a simple brass split-ring clutch using two 4-40 machine screws. The worm is reset by loosening the wing nut near the worm end of the shaft, lifting that end of the assembly and sliding the tangent arm to the forward end of the rack. There the worm is pressed into its teeth once more and the wing nut tightened. To prevent accidental jamming of the worm at the close of a two-hour run, a microswitch is placed at the end of the rack.

The worm shaft was necessarily extended to a point on the sector arc where it would clear the bottom of the motor and still allow proper seating of the worm. True, having the worm inclined 90 degrees to the rack axis causes a mismatch, but molding the rack to the sector stretches the pitch enough to allow the worm to drop into its proper place in the teeth.

The accuracy of a synchronous-motor drive depends on that of the power company's frequency, and that in turn depends on the power pool involved. For example, in Des Moines, Iowa, the frequency lead or lag does not exceed about 1/100 of one cycle over a three-hour period, and such an error exists for only a few minutes before being corrected. The Northwest power pool, which establishes our frequency in Denver, is about one-third to one-fourth this good.

Consequently, I plan to add a frequency control for the motor, which will permit me to guide with a push-button unit. For although I intended this to be only a temporary driving mechanism, it has been completely satisfactory and is now my permanent one. The labor was so simple that I was able to construct the whole device in only a few days preceding an observing session of the Denver Astronomical Society. I even had time to paint it!

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TELESCOPE MIRRORS

Better than 1/8 wave.

Guaranteed to resolve to Dawes' limit.

6-inch	$52.50
8-inch	$79.90
10-inch	$165.00

No C.O.D.'s, please. Pennsylvania residents add 4% sales tax.

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ANOTHER QUESTAR OWNER WRITES

"If my previous letter can help you in any small way to introduce Questar to people who are in a quandary as to the purchase of a telescope, you are welcome to put it to any use you see fit. I have enjoyed my Questar beyond words of expression and believe that dollar for dollar it is the best investment I have ever made.

"There must be a large group of potential telescope buyers who are at the brink of a decision whether to buy a telescope based on appeal, performance, or cost.

"Comparing Questar to other instruments, a person is apt to fall for instruments whose sales appeal is largely based on a lot of useless and impotent accessories. After using that kind of telescope for a while, he usually advertises it for sale at a reduced price or if money is a problem, he learns to live with it even if he is not happy with it. Later if he is fortunate enough to peek through a Questar, his misery is compounded because he realizes he has missed a good bet." — *Mr. Joseph Synow, California.*

STAR-TESTED QUESTARS ARE USUALLY IN STOCK READY FOR IMMEDIATE DELIVERY, FROM $995. TERMS ARE AVAILABLE. LET US SEND YOU THE QUESTAR BOOKLET.

a preview of the good things to come

Here, in all its array of precision components, pieces and paraphernalia, is the UNITRON 4" Photographic Equatorial Model 160.

We hope this picture, a thousand times better than words, may suggest to you something of that inevitable glow of surprise and pride that comes to the new UNITRON owner who, for the first time, opens his newly arrived telescope cabinets and discovers how much he has bought . . .

This sense of discovery . . . this sheer delight that comes with the realization that you have received even more value than you expected . . . is only the very first of the myriad pleasures the Model 160 has in store for you. For, like all UNITRONS, this model promises enough pleasant surprises to last a lifetime.

HERE'S WHAT YOU GET WITH THE MODEL 160:

- 4" refractor
- Clock drive — weight driven, with governor and speed regulator
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- Metal tripod shelf with levels
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- Star diagonal
- Uniclamp mounting brackets
- Uniclamp camera bracket
- 10x 42-mm. view finder
- Super rack-and-pinion focusing mechanism with clamps
- 8 eyepieces: 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x
- Unihex rotary eyepiece selector
- Erecting prism system
- Sun projecting screen
- Sunglass
- Solar aperture diaphragm
- Unibalance tube assembly
- Pocket eyepiece case
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$1175

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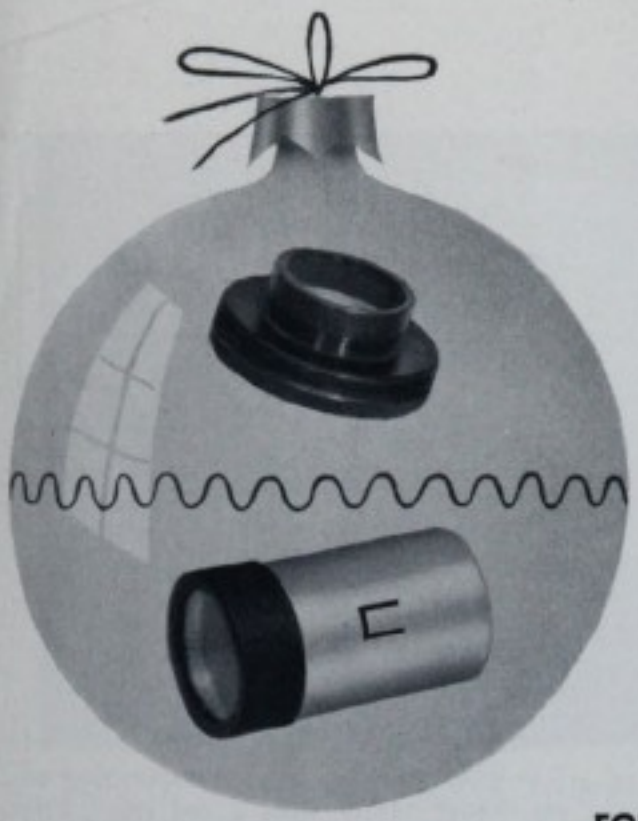
SEE THE BACK COVER FOR MORE ABOUT UNITRON.



PLEASE ACCEPT THIS SUPERB NEW ACHROMATIC AMPLIFIER –

yours free when you join the growing family of lucky astronomers who will be buying a UNITRON this Christmas!

UNITRON's new Achromatic Amplifier is a two-element, Barlow-type, negative amplifying lens designed especially for UNITRON refractors.

When used with a UNITRON eyepiece, it **doubles** the normal magnification of the telescope. Here is the ideal way to increase the usefulness of each eyepiece, and to obtain the high magnifications you have always wanted for planetary or lunar observations. (The magnification factor of 2x has been selected as the most useful for general amateur observation under a wide variety of atmospheric conditions.)

Two types of mounting cells are offered for the Amplifier, one to fit the UNIHEX Rotary Eyepiece Selector and one for the UNITRON Star Diagonal. Either type can be inserted or removed in a jiffy. There are no cumbersome tubes to attach, nor ever any need to adjust the focus of the eyepieces in the UNIHEX or star diagonal. The unique optical design matches the UNITRON objectives and eyepieces to insure sharp definition without loss of resolution.

This useful and valuable accessory will be included as standard equipment with each UNITRON at no additional cost . . . still another reason why this Christmas and every Christmas your choice should be a UNITRON.

FOR YEAR-ROUND PLEASURE

Above is America's most popular portable — the UNITRON 2.4" Altazimuth. At the left are two more instruments — the magnificent UNITRON 6" Photo-Equatorial and the 4" Model 166V.

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1. **VIEW FINDER**, 23.5-mm. (.93"), 6x eyepiece. **Only $8.50**
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All finders have coated optics, achromatic objectives, crosshair eyepieces, and come complete with mounting brackets and centering screws. Shipped postpaid.

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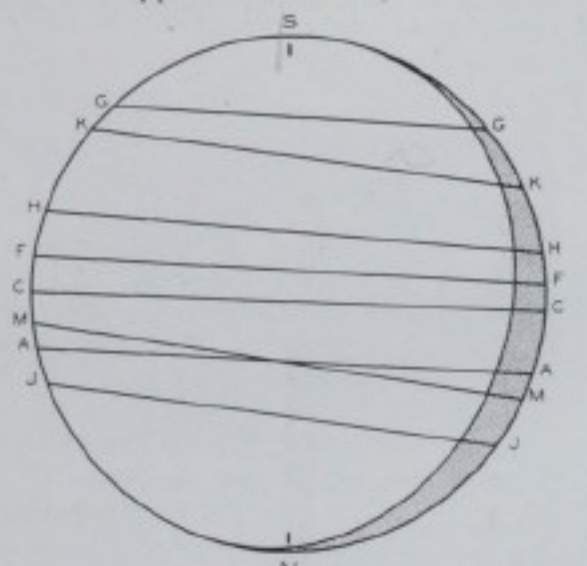
CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

Two Occultations of Aldebaran

TWICE during December the moon again will cover 1st-magnitude Aldebaran. On the early evening of December 2nd, the star will be occulted for watchers in the eastern and central parts of the United States and Canada. The second event, visible throughout both countries, is on December 29-30. An excellent impression of the appearance of the phenomenon in a telescope is given by the pictures on page 348 (facing the Occultation Supplement for 1961).



On December 29-30 observers throughout the United States and Canada will see an occultation of Aldebaran. The star's apparent leftward path relative to the moon is plotted here for eight standard stations.

The moon will be only a few hours before full during the December 2nd event, and the glare may make Aldebaran difficult to detect unless the sky is very clear. At Washington, D. C., the star will be covered by the moon from 23:20 Universal time to 0:15 (6:20 p.m. to 7:15 p.m. Eastern standard time). At Chicago, the occultation lasts from 23:30 UT to 0:10 (5:30 p.m. to 6:10 p.m. CST). For Denver, immersion will not be observable, as the star is still too low, but Aldebaran will reappear from behind the moon at 0:03 UT (5:03 MST). Predictions for other geographical locations can be made from the data in the 1960 Occultation Supplement (Sky and Telescope for December, 1959).

On December 29-30, the moon will be 12 days old, and Aldebaran disappears at the dark limb. Predicted times for a dozen localities are given in the table, and the track of the star relative to the moon is charted for several of these places. Generally speaking, the conditions of visibility will be much more favorable than on December 2nd, and small telescopes should give good views of the event.

PREDICTED TIMES FOR DECEMBER 29-30 OCCULTATION OF ALDEBARAN

Station	*Location*	*Disapp.*	*Reapp.*	*Time*
A	Massachusetts	3:07 a.m.	4:06 a.m.	EST
B	Montreal	3:04 a.m.	4:01 a.m.	EST
C	Washington, D. C.	3:09 a.m.	4:11 a.m.	EST
D	Toronto	3:03 a.m.	4:05 a.m.	EST
F	Illinois	1:58 a.m.	3:07 a.m.	CST
G	Texas	2:10 a.m.	3:04 a.m.	CST
H	Denver	0:42 a.m.	1:57 a.m.	MST
I	New Mexico-Arizona	0:47 a.m.	1:51 a.m.	MST
J	Edmonton, Alberta	0:22 a.m.	1:30 a.m.	MST
K	California	11:19 p.m.	0:34 a.m.	PST
L	Oregon	11:09 p.m.	0:34 a.m.	PST
M	Vancouver, B. C.	11:05 p.m.	0:25 a.m.	PST

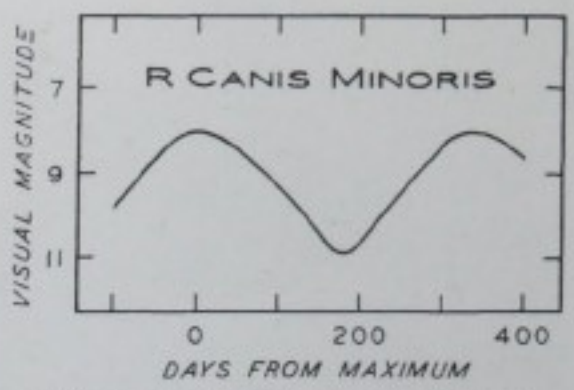
R CANIS MINORIS

ABOUT nine degrees northwest of Procyon, and close to the point where the constellations Canis Minor, Gemini, and Monoceros meet, is the variable star R Canis Minoris. Changing in brightness by some three magnitudes in an 11-month cycle, it is scheduled to attain a maximum brilliance of magnitude 8.0 around December 17th.

This faint star near the northern edge of the Milky Way will be scrutinized by scores of those amateurs in all parts of the world who systematically follow the light changes of variables. Other records of it will be obtained this winter by the patrol cameras at German and Soviet observatories, where the skies are continually being remapped photographically. Also, perhaps one of the giant reflectors in California will be used for another picture or two of this variable's unusual spectrum.

The fluctuations of R Canis Minoris were first noted at Bonn Observatory, in 1855, and since then it has been one of the most closely followed of variables. With an average magnitude range of 8.0 to 11.0 visually, it is properly called a Mira-type variable rather than a long-period variable, the latter term being used nowadays only if the amplitude is less than 2.5 magnitudes. The average interval between maxima is 337.93 days, according to the 1958 Moscow *General Catalogue of Variable Stars*.

In S. C. Chandler's old listing of the colors of variables, R Canis Minoris is rated as of color 5.5 on the scale of 0 = white to 10 = red, corresponding to an orange rather than a red star. The spectrum belongs to the rare type *S*. This star is located at right ascension 7h 06m.0, declination +10° 06′ (1950 co-ordinates).



This light curve for the variable R Canis Minoris was derived by the late Leon Campbell from observations by members of the American Association of Variable Star Observers. From "Studies of Long Period Variables."

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.

FIRST REPORTS OF MERCURY'S TRANSIT

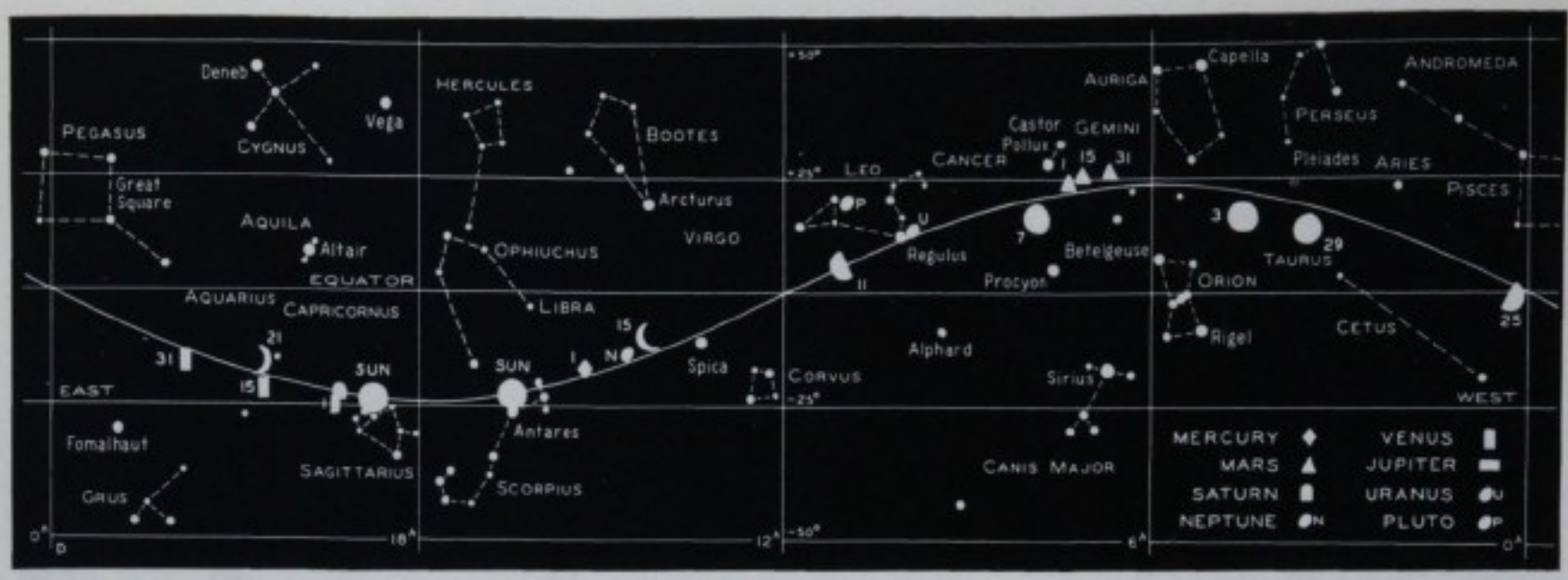
(Continued from page 319)

serving to isolate the planet and its immediate surroundings. This experiment with a 12-inch f/66 Cassegrainian was hampered by cirrus clouds. W. H. Haas, P. Engle, and G. Kraus observed with 17-inch and 6-inch telescopes at Edinburg, Texas. From Las Vegas, Nevada, seeing of 7 and transparency 5 were reported by T. Constanten.

Along the West Coast, the weather was less favorable. In the Los Angeles area, R. Ensign, L. Robinson, and J. Biela, at Fullerton and Anaheim, were clouded out before contacts III and IV. At Manhattan Beach and Hollywood, however, these events were successfully observed, in spite of intermittent clouds, by J. Eastman, R. Edwards, M. Gardner, and A. McClure. In West Los Angeles, L. Chilton lost the egress in clouds.

Farther up the coast, at Templeton, California, W. S. York timed the end of the transit in spite of poor weather, but at Cupertino, W. Krumm had only a brief glimpse of the planet three-fifths of its way across the sun. In the Northwest, skies cleared at Yakima, Washington, in time for J. McHugh to observe the third contact's black-drop effect.

From these preliminary reports, it is evident that American amateurs made special efforts to observe a striking celestial event that will not recur until May 9, 1970.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0h Universal time on the respective dates.

Mercury rises about 1½ hours before the sun on December 1st, and may be seen low in the eastern sky during dawn the first few days of the month. Thereafter it is too close to the sun to be viewed.

Venus at midmonth is a brilliant object of magnitude −3.7, shining in the southwestern sky for nearly three hours after sunset. On the 15th the planet will show in a telescope a gibbous disk 16″.6 in diameter and 70-per-cent illuminated.

Earth reaches heliocentric longitude 90° at 20:27 Universal time on December 21st. Winter begins in the Northern Hemisphere, summer in the Southern.

Mars is well placed for observation all month as a bright reddish object in Gemini. On the 30th the planet comes to opposition with the sun and rises about sundown, its magnitude being −1.3. Mars will be closest to the earth five days before this, on December 25th, at a distance of 56 million miles, with its disk 15″.4 in apparent diameter.

Jupiter sets two hours after the sun at the beginning of the month, when it is of magnitude −1.4 and conspicuous in Sagittarius in the southwestern sky. However, Jupiter rapidly approaches the sun, and by midmonth will be lost in its glare.

Saturn is located in Sagittarius approximately 8° east of Jupiter. On the 15th, at magnitude +0.8, it sets two hours after the sun. The ringed planet follows Jupiter into the solar glare, becoming lost to view by the end of the month.

Uranus on the 15th is a 6th-magnitude object in Leo, at right ascension 9h 52m.3, declination +13° 42′ (1950 co-ordinates). It rises more than two hours before midnight, local time, and may be easily seen in binoculars. Telescopically, its small greenish disk is 3″.8 in diameter.

Neptune is an 8th-magnitude planet in Libra, rising a few hours before the sun in mid-December. At this time the planet is at 14h 33m.6, −13° 15′ (1950), visible in the eastern sky with small telescopes.

WILLIAM H. GLENN

MINIMA OF ALGOL

December 3, 7:17; 6, 4:06; 9, 0:56; 11, 21:45; 14, 18:34; 17, 15:23; 20, 12:13; 23, 9:02; 26, 5:51; 29, 2:40; 31, 23:30.

January 3, 20:19; 6, 17:08; 9, 13:58.

These minima predictions for Algol are based on a recent timing by D. Engelkemeir, and an assumed period of 2.8674 days. The times given are geocentric; they can be compared directly with observed times of least brightness.

MINOR PLANET PREDICTIONS

Europa, 52, 10.4. December 2, 6:41.5 +16-03; 12, 6:34.9 +16-17; 22, 6:26.6 +16-39. January 1, 6:17.8 +17-06; 11, 6:09.4 +17-38; 21, 6:02.0 +18-12. Opposition on December 27th.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

ALGOL OBSERVATIONS

Donald K. Engelkemeir, Hinsdale, Illinois, reports photoelectric observations of the variable star Algol on October 1, 1960, finding that geocentric minimum occurred at 5:11.6 UT, corresponding to Julian day 2437208.7224 (heliocentric). This is 33 minutes later than the Sky and Telescope prediction. Dr. F. B. Wood writes that photoelectric observations at Flower and Cook Observatory confirm this, and demonstrate that Algol's period has recently changed considerably.

New determinations of times of minima are highly desirable, whether visual or photoelectric. The accompanying ephemeris is a revision, based on preliminary new elements.

Dr. Wood also writes that the observed minimum by K. C. Chou (January, 1960, issue, page 190) was incorrectly reported, and should read JD 2436861.7654 (heliocentric).

DECEMBER METEORS

Both of this month's important showers, Geminid and Ursid, are visible at maximum without serious interference from moonlight.

The Geminids reach maximum on the night of December 12-13, when the radiant is near Castor. At that time an observer may be able to see as many as 50 meteors per hour. This shower extends over a six-day interval.

The Ursids have a two-day extent, and should reach maximum at 12:00 Universal time (6 a.m. Central standard time) on December 22nd this year. The rate for a single observer may be 15 meteors per hour. About eight of these would belong to the shower, whose radiant lies close to the bright star Gamma Ursae Minoris.

WILLIAM H. GLENN

VARIABLE STAR MAXIMA

December 11, T Centauri, 133633, 5.5; 17, R Canis Minoris, 070310, 8.0; 17, RV Sagittarii, 182133, 7.8; 21, RS Cygni, 200938, 7.2; 22, X Centauri, 114441, 8.0; 30, R Leonis Minoris, 093934, 7.1.

January 3, S Sculptoris, 001032, 6.8; 3, S Pegasi, 231508, 8.0; 6, R Ophiuchi, 170215, 7.9; 7, T Aquarii, 204405, 7.7; 8, R Normae, 152849, 7.2.

These predictions of variable star maxima are by the AAVSO. Stars are listed only if brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

MOON PHASES AND DISTANCE

Full moon	December 3,	4:25
Last quarter	December 11,	9:39
New moon	December 18,	10:47
First quarter	December 25,	2:30
Full moon	January 1,	23:06

December	Distance	Diameter
Apogee 7, 3h	252,100 mi.	29′ 27″
Perigee 19, 11h	222,800 mi.	33′ 20″
January		
Apogee 3, 13h	252,500 mi.	29′ 24″

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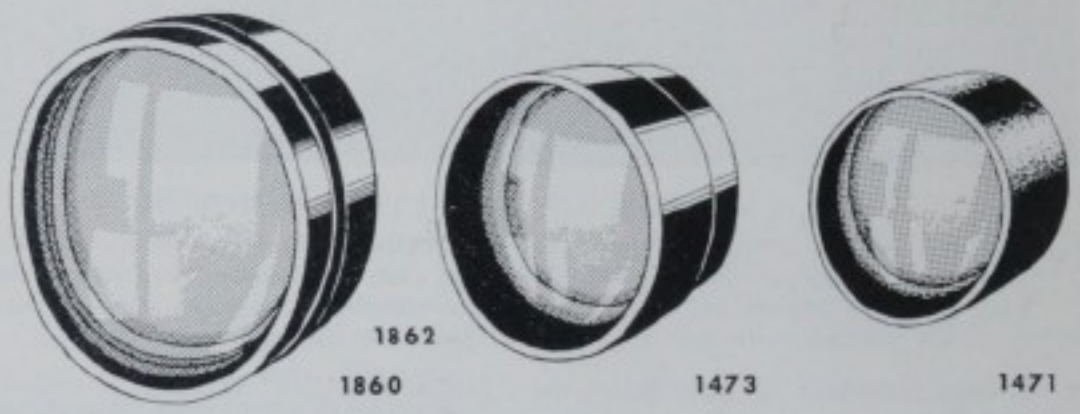

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S1437	7 x 35 IF	341	"Zeiss"	17.95
S1771	7 x 35 CF	341	American	23.50
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Monoculars

Brand new, coated optics, complete with pigskin case and neck straps.

Cat. No. S1576	6 x 30	$10.00	ppd.
Cat. No. S1577	8 x 30	11.25	ppd.
Cat. No. S1578	7 x 35	12.50	ppd.
Cat. No. S1303	7 x 50	14.75	ppd.
Cat. No. S1579	16 x 50	17.50	ppd.
Cat. No. S1580	20 x 50	20.00	ppd.

New! Zoom Binoculars

Six different powers at your fingertips in the same binocular: 7x, 8x, 9x, 10x, 11x, and 12x. Positive fingertip control accomplished by rotation of eyecups. Popular Center Focus, American type, 40-mm. objective, all coated optics. Complete with carrying case and straps. **Price plus 10% Federal tax.**

Cat. No. S2303 ..... $39.75 ppd.

4¼" Reflector Telescope

35x — 175x
4x Finder — Wood Tripod

From the mysterious craters of the moon to the fabulous rings of Saturn, this high-quality telescope will give you many pleasurable hours of crystal-clear astronomical viewing. Contains an f/6 parabolic mirror which gives a 50-per-cent brighter image than the ordinary f/10. Two coated eyepieces, 35x and 175x; rack-and-pinion focusing; sun filter; and 4x focusing finder. Its short tube, 27¼" long, and collapsible wood tripod (33" closed, 60" open), make for portability, stability, and compactness. Finished in white enamel with black trim. Imported. Shipping weight about 20 lbs.

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Cat. No. S2273 ..... f.o.b. Lynbrook, N. Y., $59.50

8-Power Elbow Telescope

This telescope has a brilliant-image 48° apparent field; actually 325 feet at 1,000 yards. Can be adjusted for focusing 15 feet to infinity. 2" achromatic objective, focusing eyepiece 28-mm. f.l., Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night use. Truly the biggest bargain you were ever offered. Original Govt. cost $200.

8 x 50

Cat. No. S1686 Not Coated ..... $13.50 ppd.
Cat. No. S1975 Coated ..... $17.50 ppd.

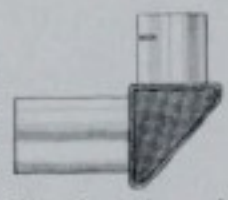
A Beginner's Guide to the Skies

R. Newton Mayall and Margaret W. Mayall

"Probably the best handbook now available for a newcomer to amateur astronomy." — *Sky and Telescope.* Contains a wealth of information about the solar system, and many lists of objects to be observed with binoculars or a telescope; includes 100 pages of detailed charts and observing data, arranged alphabetically by constellation. 184 pages. Cloth bound.

Cat. No. S2301 ..... $2.50 ppd.

Star Diagonals



Guaranteed to make viewing the heavens with a refractor telescope 100% easier for the observer. Stop needless crouching forever. Choose the STAR DIAGONAL that best suits your requirements. Slides into standard 1¼" eyepiece mounts. Chromium tubes and aluminum housing, attractive black-crackle finish.

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For comfortable viewing of terrestrial or astronomical objects. The Amici prism gives an erect image.

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RIGHT-ANGLE PRISM STAR DIAGONAL

Contains a high-quality aluminized right-angle prism, wide field. Practical for astronomical use.

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MIRROR STAR DIAGONAL

Diagonal houses an excellent first-surface mirror, flat to within ¼ wave. Important accessory for refractor telescopes.

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7 x 30 Wide-Field Finderscope

Newly designed wide-field finderscope for reflector or refractor. Featured in this handsomely conceived black anodized aluminum tube are a 30-mm. coated achromatic objective, a wide-field Kellner eyepiece, and the all-important true crossline reticle for fast, exact locating. Compact and lightweight, 9" long, 1½"-diam., 9 oz. May also be used as a hand-held telescope, offering excellent extra-wide-field views of the sky.

Cat. No. S2193 ..... $9.75 ppd.

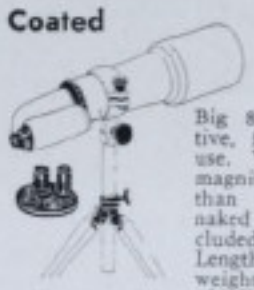
Finder Ring Mounts

Will accommodate finder above. Made of cast aluminum with black crackle finish. Each ring has three locking wing screws for adjusting. Base has two holes for mounting screws, fits any diameter tubing. Easy to mount. Inside diameter of ring mount 1-15/16".

Cat. No. S1963 ..... Per Pair ..... $3.95 ppd.

New Prismatic Telescope

Coated **80-mm. Objective**



Big 80-mm.-diam. (3⅛") objective, for spotting or astronomical use. Will show stars of the 11th magnitude — 100 times fainter than the faintest visible to the naked eye. Table-top tripod included, extended 18", closed 13¼". Length of scope 16¼". Combined weight of scope and tripod is 5¼ lbs. All coated optics.

FIVE EYEPIECES

Power	Field at 1,000 yards	Exit pupil diam.	Relative Brightness
15x	122 ft.	5.4 mm.	29
20	122	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

Cat. No. S2052 ..... $59.50 ppd.

60-mm.-diam. Scope. Same as above but with smaller objective. Equipped with same five eyepieces — 15x, 20x, 30x, 40x, 60x. Coated. With tripod.

Cat. No. S1721 ..... $42.95 ppd.

Mounted Eyepieces

The buy of a lifetime at a great saving. First choice of the amateur and professional astronomer. Perfect lenses set in black anodized standard 1¼" O.D. aluminum mounts.

Cat. No.	F.L.	Type	ppd.
S2192	6 mm. (¼")	Orthoscopic	$13.25
S1851	6 mm. (¼")	Ramsden	4.75
S1853	12.5 mm. (½")	Ramsden	4.50
S1207	12.5 mm. (½")	Symmetrical	6.00
S1251	16 mm. (⅝")	Erfle (wide-angle)	12.50
S1257	16 mm. (⅝")	Orthoscopic	12.50
S1209	18 mm. (¾")	Symmetrical	6.00
S1211	22 mm. (27/32")	Kellner	6.00
S1835	27 mm. (1-1/16")	Kellner	4.50
S1355	32 mm. (1¼")	Plossl	12.50
S1253	35 mm. (1⅜")	Symmetrical	8.00
S1255	55 mm. (2-3/16")	Kellner	6.00
S1485	56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

"Giant" Wide-Angle Eyepiece

Coated Lenses

Erfle eyepiece best for low-power performance. Superior six-element design. 65° field, 1½" E.F.L., clear aperture 2¼", focusing mount and diopter scale. Combine this eyepiece with our 5" objective No. S1475 for a tremendous light-gathering Rich-Field Telescope.

Cat. No. S1405 (illustrated) ..... $12.50 ppd.
Cat. No. S1858 Same as above without diopter scale ..... $ 9.95 ppd.

● **FREE RUBBER EYESHIELD** ●
With S1405

Cat. No. S1594 1¼"-diam. ADAPTER for eyepiece above ..... $ 3.95 ppd.

ADAPTER PLATE AND TUBE. Aluminum tapered tube and adapter plate, black anodized and finished in black crackle. Slides into our 5" O.D. Aluminum Tubing No. S1511. These parts are used with the eyepieces above to make a Rich-Field Telescope. Details in our catalogue.

Cat. No. S2300 ..... $18.00

Wide-Angle Erfle

Brand-new eyepiece with 68° field; coated. E.F.L. 1¼". Focusing mount, 3 perfect achromats, 1-13/16" aperture.

Cat. No. S1020 ..... $13.50 ppd.
Cat. No. S1593 1¼" diam. ADAPTER for eyepiece above ..... 3.95 ppd.

An Economical Eyepiece

This mounted eyepiece has two magnesium-fluoride-coated achromatic lenses 29 mm. in diameter. Excellent definition. E.F.L. 1¼". Cell fits 1¼" tubing.

Cat. No. S1911 Coated ..... $5.90 ppd.
Cat. No. S1991 Not Coated ..... 5.25 ppd.

Rack-&-Pinion Eyepiece Mounts

Here is a wonderful opportunity for you to own a most mechanically perfect Rack-&-Pinion Focusing Eyepiece Mount with variable tension and adjustment. Will accommodate a standard 1¼" eyepiece, positive or negative. The body casting is made of lightweight aluminum with black-crackle paint finish, focusing tube of chrome-plated brass. Focusing tube for refractors has a travel of 4", for reflectors 2", and will fit all size tubing.

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Cat. No. S1494	for 2⅛" I.D. Tubing	$12.95 ppd.
Cat. No. S1495	for 3¼" I.D. Tubing	12.95 ppd.
Cat. No. S1496	for 4⅛" I.D. Tubing	12.95 ppd.

REFLECTOR TYPE

Cat. No. S1976	(less diagonal holder)	$8.50 ppd.
Cat. No. S1982	DIAGONAL HOLDER	1.00 ppd.

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SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 5th and 20th of February; also, at 9 p.m. and 8 p.m. on March 8th and 23rd. For other dates, add or subtract ½ hour per week.

Almost overhead at chart time appears the False Cross, made of stars in Vela and Carina. It should not be confused with the true Southern Cross, farther east along the misty band of the Milky Way. Crux has found a place on the national flags of both Australia and Brazil.

STARS FOR DECEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 6th and 21st of December, respectively; also, at 7 p.m. and 6 p.m. on January 6th and 21st. For other dates, add or subtract ½ hour per week.

Contrast the densely starred constellations now overhead in the Milky Way with the relatively few stars visible in the southern sky. Try to pick out faint Fornax the Furnace and follow the course of Eridanus the River Po tó the southern horizon.

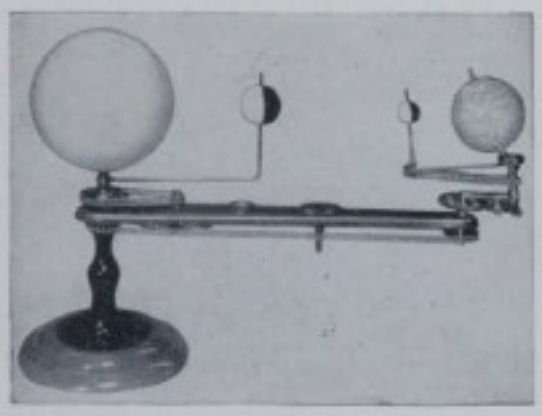
Astronomy Teaching Aids ★ ★ ★ ★ ★ ★ ★

DeLuxe Celestial Globes

No. 740. Our finest 16″ globe, designed as a visual aid by teaching astronomers. All stars of the first six magnitudes are shown on a pale blue background, with the first three magnitudes having bright yellow, circular backgrounds. Brighter stars are named, and constellation boundaries indicated. Declination and right-ascension circles are printed in black. Magellanic Clouds and Milky Way stand out in white, and important star clusters are indicated. Various bases available. Weighted table base illustrated. $67.50

No. 742. 12″ Celestial Globe. Shows stars down to 5th magnitude on a light blue background. Constellations named. On weighted table base with movable meridian and horizon. $35.25

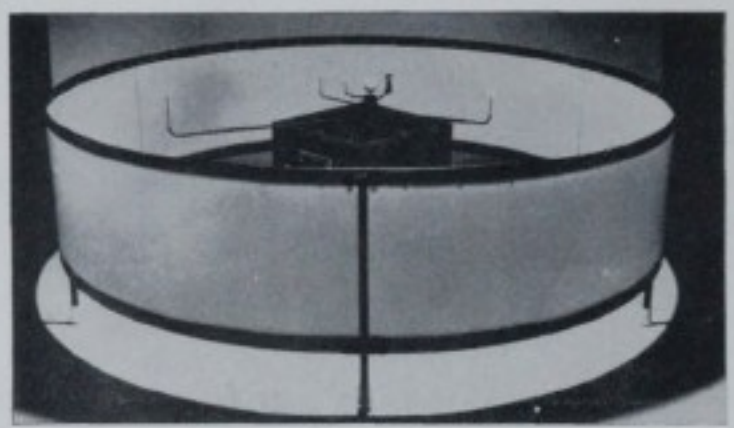
No. 745. 30″ Illuminated Rotating Celestial Globe. A translucent plastic globe illuminated by electric light. Shows stars down to 10th magnitude. Background includes brightly colored figures from celestial mythology. Base houses a motor to produce one complete rotation of the globe every 1½ minutes. Attractive modern base supports globe. $1,185.00



Trippensee Planetarium

No. 708. This demonstration device shows the relative positions and motions of the Sun, Earth, Moon, and Venus. Simplifies teaching the rotation of the earth, the annual revolution around the Sun, day and night, change of seasons, and the cause of eclipses. This is an orrery-type device and not a projection planetarium. Constructed of brass with chain-drive gears. Arm length is 16½″, overall height 16″. Hand operated. $96.50

Spitz Shadow Orrery



No. 712. An ingenious classroom device to demonstrate in a minute the intricate movements of the six major planets. One may view them as from outer space, all moving in the same direction around the Sun. Then, in an instant, the motion of the planets can be seen as from the moving Earth. The inferior motions of Mercury and Venus from one side of the Sun to the other can be clearly demonstrated, as can the forward and retrograde apparent motions of Mars, Jupiter, and Saturn in their exterior orbits. $295.00

Transparent Globes

No. 736. A combination globe device consisting of an outside celestial globe showing stars and constellations and an inside brightly colored 6″ terrestrial globe. Unique star pointer simulates Sun's motion. Demonstrates many Earth-sky-Sun relationships.

No. 736 — 12″ Globe $49.50

No. 736 — 20″ Globe $115.00

Practical Telescopes

No. 755. 4.5″ Reflector. Designed for students and teachers, approved under NDEA for high schools. Optical system: 4.5″ mirror, f/11, spherically corrected with surface accurate to ⅛ wave. Three eyepieces: Kellner 50x, Ramsden 100x, Ramsden 200x. Mounting: equatorial and adjustable for latitude. Tube: seamless aluminum, 45″ long. Pedestal: heavy-wall steel tube with collapsible legs, free from wobble and torque. $98.50

No. 757. 4.5″ Electra. Same optical system as above, but with synchronous electric motor drive and slow-motion control in declination. $149.50

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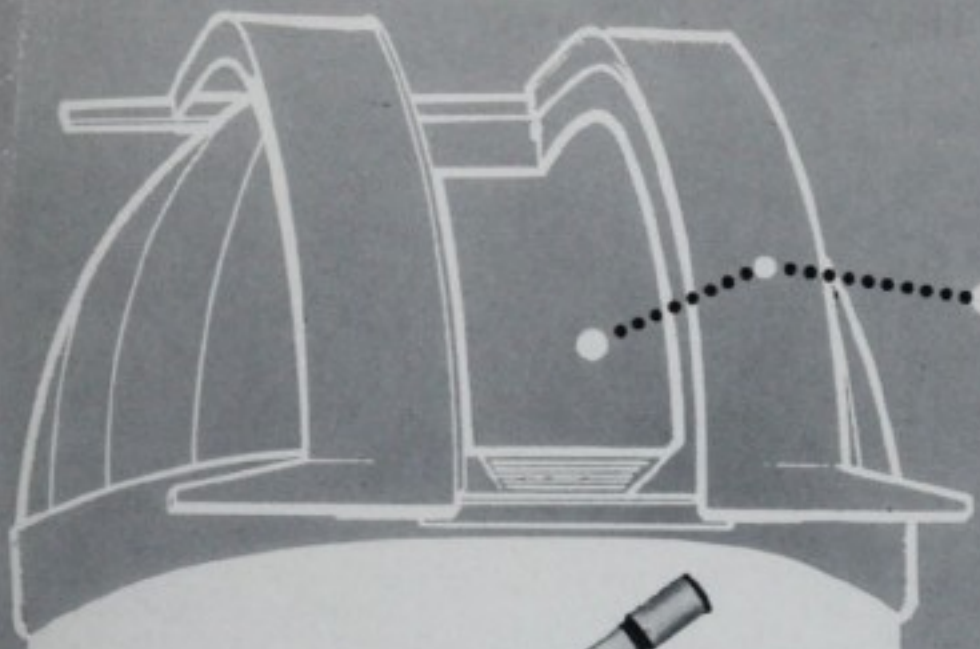

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PATENTS PENDING

GOTO 8-INCH (20-CM.) EQUATORIAL

This fine observatory-type instrument has extreme versatility for all types of observing, and comes equipped with a star spectroscope and two cases full of accessories. It has an equatorial mounting, with large right-ascension and declination circles, and slow-motion controls.

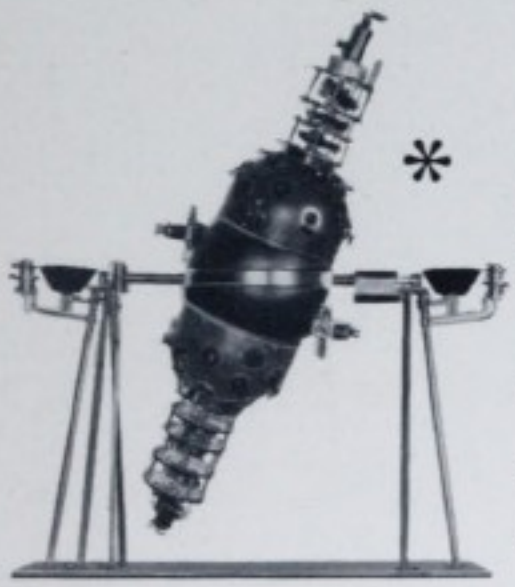
ACHROMATIC OBJECTIVE: Clear aperture 200 millimeters, focal length 3,000 mm., giving a focal ratio of f/15. Its theoretical resolving power on double stars is 0.58 second of arc, and it can detect stars of visual magnitude 13.3 in a perfectly transparent sky.

ELECTRIC CLOCK DRIVE: A magnetic speed adjuster gives complete control in right ascension.

GUIDE TELESCOPE AND FINDER: 80-mm. and 50-mm. apertures, respectively, giving powers of 30x and 7x.

EYEPIECES AND ACCESSORIES: Eight oculars, Herschel solar prism and solar projecting screen, star or zenith diagonal for viewing overhead objects, iris diaphragm to reduce objective aperture, three sun filters, three moon filters, and star spectroscope.

FINISH: The entire telescope and assembled parts and pier are handsomely finished in white and light gray, to blend with any modern observatory interior.



GOTO M-1 PLANETARIUM PROJECTOR

FEATURES:

1 Each individual projection unit has its own optical lens system, so very sharp star images are produced on the planetarium dome.

2 The entire celestial sphere is reproduced, and may be viewed as if the audience were anywhere in the world, including polar regions.

3 The apparent motions of the moon, sun, and five bright planets are reproduced at accelerated speeds.

4 The celestial equator and ecliptic can be projected as great circles on the sky.

5 As with the largest planetarium projectors, all three essential motions of the projector as a unit are provided with motor control, so that . . .

- A Daily motion around the polar axis reproduces the apparent diurnal movement of the sky and causes the heavenly bodies to rise and set.
- B Latitude may be changed and a trip around the world demonstrated by turning the projector on its horizontal supports (east-west axis).
- C The Great Year of 25,800 ordinary years can be simulated, as the projector is turned around the axis of the ecliptic poles, reproducing the gyration of the poles known as precession. The changing right ascensions and declinations of the stars are thus demonstrated.

6 All necessary auxiliary projectors and controls are provided at the remote-control console, including a pointer, switches for the stars and other objects, motor switches, and the like.

ASTRO-DOME, INC., for many years makers of fine domes for observatories and scientific institutions, has now become associated with Japan's Goto Optical Manufacturing Co., well-known for their optical products of the highest quality.

Astro-Dome is now United States representative for Goto planetarium projectors and telescopes. Thus, it is now possible for astronomers and educators everywhere to use the facilities of one firm to plan a complete installation for school, college, or community education in astronomy, from observatory building and instrument through a planetarium with interior and exterior domes and associated facilities.

Astronomers at universities and colleges, school teachers, planners of civic centers and museums, all are invited to take advantage, without obligation, of our services in the preliminary planning of astronomical facilities. We can supply, without charge, sets of blueprints showing typical installations; these can be used by your architect in planning astronomical structures.

We have technicians ready to install and service planetariums and telescopes, as well as Astro-Domes and Astro-Domettes. We are also maintaining an inventory of projectors and parts for Goto equipment.

Astro-Dome, with its years of experience in dome manufacture, has had no problem in designing for planetariums interior projection screens of either fiberglass or perforated aluminum, and these are available in various diameters. We supply, of course, exterior Astro-Domes to house telescope or planetarium, as well as complete observatory and planetarium buildings.

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As a matter of fact, there's more pleasure-per-dollar in the Unitron 3-inch Altazimuth you see in this picture (or in any other Unitron) than you can find in any refractor anywhere on this planet of ours. How do we know?

Santa Claus told us. He says that there are more Unitrons delivered at Christmas (and throughout the year) than any other refractors.

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